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Decision-Makers' Guide To Solid Waste Management, Volume II

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Decision Maker's Guide to Solid Waste Management, Volume II

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PREFACE

The *Decision Maker's Guide to Solid Waste Management, Vol. II* has been developed particularly for solid waste management practitioners, such as local government officials, facility owners and operators, consultants, and regulatory agency specialists. The Guide contains technical and economic information to help these practitioners meet the daily challenges of planning, managing, and operating municipal solid waste (MSW) programs and facilities. The Guide's primary goals are to encourage reduction of waste at the source and to foster implementation of integrated solid waste management systems that are cost-effective and protect human health and the environment.

Because the infrastructure and technology for handling MSW are rapidly changing, the information presented should help decision makers consider the numerous factors associated with successful implementation of new solid waste management solutions. Readers are encouraged to carefully evaluate all of the elements in their waste-handling systems and implement source reduction, recycling, and environmentally sound disposal.

Communities are encouraged to coordinate their goals for waste reduction and management, environmental protection, community development, and employment. Communities, businesses, institutions, and individuals should apply their creativity and ingenuity in drafting policies and designing programs that prevent the generation of waste in the first place. When waste generation is unavoidable, the materials can be viewed as a resource from which reusable materials, raw feedstock, minerals, organic matter, nutrients, and energy can be recovered for beneficial uses. Residual materials requiring disposal must be carefully managed to protect human health and the environment.

We encourage all individuals involved with MSW management to expand their professional skills and to help other practitioners and community members better understand the challenges we face and the opportunities available to us. It is primarily through such cooperative enterprises that governments, communities, and businesses can make the best possible decisions for the reduction and management of municipal solid waste.

From: Decision Maker's Guide to Solid Waste Management, Volume II, (EPA 530-R-95-023), 1995. Project Co-Directors: Philip R. O'Leary and Patrick W. Walsh, Solid and Hazardous Waste Education Center, University of Wisconsin-Madison/Extension. This document was supported in part by the Office of Solid Waste (5306), Municipal and Industrial Solid Waste Division, U.S. Environmental Protection Agency under grant number CX-817119-01. The material in this document has been subject to Agency technical and policy review and approved for publication as an EPA report. Mention of trade names, products, or services does not convey, and should not be interpreted as conveying, official EPA approval, endorsement, or recommendation.

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A Note on Using This Guidebook

For a quick overview of the issues covered in each chapter, readers are encouraged to review the highlights presented at the beginning of each chapter and the margin notes appearing throughout the Guide.

Disclaimer

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INTRODUCTION

Volume I of the *Decision Maker's Guide to Solid Waste Management* cites estimates by the U.S. Environmental Protection Agency (USEPA) that 160 million tons of municipal solid waste were generated in the United States in 1989. Since Volume I was published, the estimated annual generation rate has risen to nearly 195.7 million tons (see Table I-1), and it appears that America's propensity for producing waste is not diminishing.

Volume I described a better way of dealing with the growing municipal solid waste problem. That solution, called integrated solid waste management (see Figure I-1), involves a combination of techniques and programs to manage the municipal waste stream. Using the integrated approach, a community can tailor its own unique system to prevent and handle various components of the waste stream in the most economical and environmentally sound manner. In Volume I, readers were introduced to the concept of developing a community integrated waste management system.

Volume II expands the information provided in Volume I. It offers decision makers more detailed information so they can help communities successfully implement integrated solid waste management programs. This volume will assist decision makers and technical professionals who must understand the key technical, legal, economic, political, and social issues that must be addressed to develop effective waste management programs.

Volume II focuses on municipal solid waste management issues. It does not address management of other important waste types, including hazardous waste, municipal sewage sludge, or agricultural residues.

EMERGING ISSUES

Waste management practices in the United States are continually changing. Public and private activities at the local, state, federal, and even international levels are having major impacts on community waste management programs. Following are just a few examples of emerging issues that will greatly affect waste management decision making.

Technical requirements for facility siting and operating are becoming more stringent.

Technical requirements for siting and operating waste management facilities are becoming more stringent. Federal and state laws require that landfills have engineered safeguards such as liners, leachate collection systems, gas management, and environmental monitoring. New laws require that waste-to-energy facilities have special technology for capturing emissions and that ash residues be specially managed. Standards for work place safety and working conditions are likely for waste management facilities such as recycling centers and composting operations. These new technical requirements will probably increase the cost and the public scrutiny of proposed methods for managing waste.

Government procurement policies are stimulating recycling markets.

New state and federal guidelines requiring that governments procure products made from recycled materials are stimulating development of recycling markets. Procurement laws should spur the development of new capacity for recycling a variety of products, especially paper. Market development is expected to increase worldwide, since the sale of recyclable material constitutes a major international market, especially for communities on America's east and west coasts.

The cost of integrated waste management programs is stimulating interest in source reduction and recycling.

In contrast, the true cost of alternative waste collection, processing and disposal options is not yet well understood by most communities and citizens. As these costs become clearer, source reduction and recycling efforts are likely to be more attractive options. Establishing and operating successful solid waste management programs requires the existence of steady markets for recycled products, compost, and the energy produced from WTE plants. This in turn may require increasing the demand for such products. Communities may also need to consider looking for alternative funding sources to support source reduction, recycling, and other programs. How much voters and waste generators are willing to pay for integrated waste management programs has not yet been widely determined.

Table I-1

Municipal Solid Waste Generated in 1990 (in millions of tons)

6.7%*	Glass	13.2
6.7%	Food scraps	13.2
8.3%	Plastics	16.2
8.3%	Metals	16.2
14.6%	Rubber, leather, textiles, wood	28.6
17.9%	Yard trimmings	35.0
37.5%	Paper and paperboard	73.3
	TOTAL WEIGHT:	195.7

*Percent of total waste generated.

Source: USEPA, *Characterization of Municipal Solid Waste in the United States: 1992 Update*

Despite major uncertainties facing decision makers in the United States, there will be a continuing need to address solid waste management issues in a timely manner. Decision makers and technical professionals considering how best to manage community waste must be aware of changing conditions and emerging issues, but they should not be deterred from developing waste management projects. This volume of the *Decision Makers' Guide* will help these persons understand the issues and develop successful integrated waste management programs.

EPA's hierarchy of integrated solid waste management includes:

- *Source reduction*
- *Recycling*
- *Waste combustion and landfilling.*

Figure I-1

Hierarchy of Integrated Solid Waste Management

Source Reduction

Source reduction tops the hierarchy because of its potential to reduce system costs, prevent pollution, consume resources, and increase efficiency. Source reduction is discussed in more detail in Chapter 5. Source reduction programs are designed to reduce both the toxic constituents in products and quantities of waste generated. Source reduction is a front-end waste avoidance approach that includes strategies such as designing and manufacturing products and packaging with minimum volume and toxic content and with longer useful life. Businesses, institutions, and citizens may also practice source reduction through selective buying and the reuse of products and materials.

Recycling

Recycling (including composting) is the second step in the hierarchy. It involves collecting materials, reprocessing/remanufacturing, and using the resulting products. Recycling and composting can reduce the depletion of landfill space, save energy and natural resources, provide useful products, and provide economic benefits. These options are discussed in more detail in Chapters 6 and 7.

Waste Combustion and Landfilling

Waste combustion and landfilling are at the bottom of the hierarchy—USEPA does not rank one of these options higher than the other, as both are viable components of an integrated system. Waste combustion, discussed in Chapter 8, reduces the bulk of municipal waste and can provide the added benefit of energy production. State-of-the-art technologies developed in recent years have greatly reduced the adverse environmental impacts associated with incineration, and although waste combustion is not risk-free, many communities are relying on this waste management alternative.

Landfilling, discussed in Chapter 9, is necessary to manage nonrecyclable and noncombustible wastes, and is the only actual waste "disposal" method. Modern landfills are more secure and have more elaborate pollution control and monitoring devices than earlier landfills. Environmental concerns at properly managed landfills are greatly reduced. Also, many new landfills are using methane recovery technologies to develop a marketable product.

Source: USEPA

REFERENCES

USEPA. 1992. *Characterization of Municipal Solid Waste in the United States: 1992 Update*. Washington, D.C. EPA/530-R-92-019 (July).

USEPA. 1989. *Decision Makers Guide to Solid Waste Management*. Washington D.C. EPA/530 SW-89-072 (November).

1

PUBLIC EDUCATION AND INVOLVEMENT

Developing integrated solutions for waste management problems requires public involvement. To economically and efficiently operate a waste management program requires significant cooperation from generators, regardless of the strategies chosen—buying products in bulk, separating recyclables from nonrecyclables, dropping off yard trimmings at a compost site, removing batteries from materials sent to a waste-to-energy facility, or using designated containers for collecting materials. To maintain long-term program support, the public needs to know clearly what behaviors are desired and why.

Involving people in the hows and whys of waste management requires a significant educational effort by the community. Ineffective or half-hearted education programs may confuse the public, reduce public confidence, or elicit hostility toward the program. Successful education programs must be consistent and ongoing.

Public education stimulates interest in how waste management decisions are made. And, when citizens become interested in their community's waste management programs, they frequently demand to be involved in the decision-making process. Communities should anticipate such interest and develop procedures for involving the public. When the public is involved in program design, it helps ensure that programs run smoothly.

This chapter provides suggestions for public education and involvement programs. Chapter 2 addresses public involvement in facility siting.

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1 ❖ HIGHLIGHTS

Public education and involvement are crucial.
(p. 1-3)

A successful waste management program requires wide-spread public participation. Such participation can best be obtained through early and effective public education programs, which must continue even after the program is in full swing.

Planning and research form the basis for successful education.
(p. 1-3)

Communities comprise different mixes of home owners, apartment dwellers, business people, students (from college-level to preschool), age groups, income levels, and cultures. Planners must first know their own communities well enough to design programs that meet their specific needs.

An effective education program leads people through several stages.
(p. 1-4 — 1-9)

The six stages of a successful education program include the following:

1. *Awareness:* At this stage, people are learning about something new. The goal is to let people know that a different way of handling waste may be preferable. Table 1-1 lists low-cost, medium-cost, and high-cost education methods.
2. *Interest:* After people have been made aware of waste management issues, they seek more information. Program planners must use a variety of methods to inform people. Voluntary programs require strong emphasis on promotion; mandatory programs should make clear what is required.
3. *Evaluation:* At this stage, individuals decide whether to participate or not. For even well-promoted programs, initial participation is about 50%. Making program requirements clear and easy to comply with increases participation.
4. *Trial:* Individuals try the program at this stage. If they encounter difficulty, they may opt not to continue participating. Well-publicized hot lines and clearinghouses provide additional instruction and information.
5. *Adoption:* Participation should continue to grow. Ongoing education programs solicit constructive feedback and provide new program information when necessary.
6. *Maintenance:* Ongoing incentives and education keep participation rates high.

Following this eight-stage plan facilitates public involvement.
(p. 1-10 — 1-13)

Effective waste management is a continuing process of public education, discussion, implementation and evaluation. All options should be continually investigated and actively debated, moving the community toward a consensus on the proper mix of source reduction and waste management programs.

1. *Concern:* Waste management is put on the public agenda.
2. *Involvement:* Representatives of various interest groups (regulatory officials, individuals from neighboring communities, local waste management experts, representatives from environmental and business groups) are encouraged to participate.
3. *Issue Resolution:* Interest groups make their points of agreement and disagreement clear to each other and to program planners.
4. *Alternatives:* Groups should make a list of available alternatives, including "no action."
5. *Consequences:* Economic and environmental consequences of each alternative are discussed.
6. *Choice:* Alternatives are decided upon.
7. *Implementation:* The steps necessary to carry out the program are described and potential adverse impacts are mitigated, if possible.
8. *Evaluation:* The community should continually evaluate the program and solicit input.

1 PUBLIC EDUCATION AND INVOLVEMENT

A PUBLIC EDUCATION PLAN

Planning and research are essential for developing effective education plans.

In many ways, public education is similar to developing public support in an election. Motivating the public to support a particular solid waste management program is similar to the aggressive and highly interpersonal way in which a particular candidate pursues votes. The same methods that are used to gain political support can be used to educate the public about the need for a waste prevention and management program and to enlist public participation in such a program. The education plan must begin by introducing people to waste management needs and concepts, explaining clearly how to participate, and then effectively encouraging them to adopt the desired waste management behavior. Once people are participating in the program, incentives and reinforcements can be used to maintain and increase participation rates.

Developing an effective education program requires planning and research. Program developers must use different strategies for different groups, such as home owners, apartment dwellers, business people, and school children. They must carefully consider the diversity of the local culture. Focus groups can help identify the community's level of understanding, so that achievable goals can be set. For communities with limited budgets, they must target key participant groups and apply resources to reach them. Communities should be realistic about the costs of promotional efforts and the benefits they yield (see Table 1-1). Always deliver a positive message.

Table 1-1
Methods of Publicity

Low Cost	Medium Cost	High Cost
News releases	Flyers	Commercials, T.V., radio
News advisories	Posters	Billboards
Public service announcements	Fact sheets	Media events
Community calendar announcements	Briefing papers	Calendars
Letters to the editor	Media events	Advertisements
News articles	Slide show	Public relations firm
Newsletter articles		
Speeches		
Guest spots on radio, T.V.		
Poster contests		
Church bulletin notices		

Source: Hansen, Z. *Sensible Publicity, A Guide.* Ramsey Co., Minn. Health Department, 1983

Grounded on a sound information base, an effective education program moves people through the following stages: (1) awareness, (2) interest, (3) evaluation, (4) trial, (5) adoption, and (6) maintenance. Each of the stages is discussed below.

Awareness

At the awareness stage, people encounter a new idea or a new way of doing things. At this stage, they do not possess enough information to decide whether a change in behavior is a good idea or whether they should be concerned. The goal of the awareness stage is to let people know that a different way of handling waste may be preferable to the historical way and that good reasons for considering a change in their waste management practices do exist.

A variety of methods can increase awareness (see Table 1-1). Low-cost methods include news articles and public service announcements or shows on radio and television. High-cost efforts include television commercials or billboards. Nationwide events such as Earth Day also help stimulate public awareness.

For example, the City of San Diego has developed a program informing its citizens about proper management of household hazardous materials (see Figure 1-1). The materials define household hazardous waste, provide recommendations on proper disposal and purchasing, and practices to limit generation. A phone number is listed for those seeking additional information.

Over the long term, education in schools is the best way of raising awareness. Many states now have curricula introducing school children from grades K through 12 to the concepts of source reduction, recycling, composting, and other waste manage-

Figure 1-1
Household Hazardous Materials Program

Put Toxic Waste In Its Place.

Household Hazardous Materials Program

Every day San Diegans unknowingly threaten our environment by throwing out tons of household hazardous waste with the regular trash or pouring it down the sewer or storm drain. When improperly disposed, these products can destroy our environment by polluting the air, water and soil.

It is dangerous, and **illegal**, to dispose of household hazardous waste improperly. Refuse collectors and landfill operators can be blinded, seriously burned or overcome with fumes when acids, corrosives or flammables are carelessly thrown in the garbage. Improper storage and handling of household hazardous waste can result in fires, poisonings and explosions.

What Is Household Hazardous Waste?

Household hazardous waste is the discarded, unused or leftover portions of household products containing toxic chemicals. Any product which is labeled *WARNING, CAUTION, POISONOUS, TOXIC, FLAMMABLE, CORROSIVE, REACTIVE or EXPLOSIVE* is considered hazardous.

Today, hazardous materials can be found in almost every house and come in many forms, including household cleaners, automotive products, paints and solvents, and pesticides.

How Can You Control Household Hazardous Materials?

When shopping for, using or storing household products, keep the following tips in mind.

- Buy only what you need
- Choose the least-toxic product
- Select water-based products over solvent-based products
- Avoid aerosol sprays
- Do not mix cleaning products containing chlorine with ammonia or acid-based cleaners
- Check storage areas at least twice a year, and dispose of products which will not be used again
- Make sure containers are tightly sealed and upright
- Keep toxic materials in their original containers and out of reach from children

How Should Household Hazardous Materials Be Disposed?

The leftover and unused portions of household hazardous materials should never be thrown in the trash or poured down the drain. Instead, use up the material as it was intended, carefully following label directions, or ask others if they could use the remaining portion. Also, you can take your household hazardous waste to a scheduled community collection event or contact the Household Hazardous Materials Program for other recycling and disposal options.

The Household Hazardous Materials Program.

The Household Hazardous Materials Program wants you to know about opportunities to reduce the amount of household hazardous waste in your home. The program provides safe disposal options for hazardous waste from households throughout San Diego County. Through community education programs and collection events, the program is working to keep San Diego's environment safe. For further information on household hazardous materials, the community education program or future collection events, please call the Household Hazardous Materials Program, **(619) 338-2267**.

The Household Hazardous Materials Program is funded by the County and City of San Diego.

Common household hazardous materials include:

Aerosols
All-purpose cleaners
Ammonia
Anti-freeze
Automobile cleaner
Barbecue lighter fluid
Batteries
Brake fluid
Chlorine bleach
Cosmetics
Detergents
Disinfectants
Drain opener
Furniture polish
Gasoline
Glass cleaner
Herbicides
Insecticides
Mothballs
Motor oil
Oven cleaner
Paint
Paint thinner
Pesticides
Rodent poison
Rubber cement
Rug & upholstery cleaner
Scouring powder
Silver polish
Snail and slug killers
Toilet bowl cleaner
Transmission fluid
Tub and tile cleaner
Turpentine
Varnish
Water seal
Wood finish

Source: City of San Diego, California

ment techniques. The Town of Islip, New York, uses a dinosaur symbol, always popular with children, to promote and explain its recycling program (see Figure 1-2). Besides educating the next generation of citizens, school programs indirectly help make parents aware of waste issues, because children frequently take home information they have learned and discuss it with their parents.

Figure 1-2
Dinosaur Symbol Used on Recycling Materials to Enhance Appeal of Mandatory Programs

Source: WRAP (We Recycle America...and Proudly) Islip, New York

Programs aimed at children should be sensitive to cultural diversity. For example, in some cultures it is considered disrespectful for children to tell their parents how to conduct themselves. For these citizens, use alternative approaches.

Interest

In the second stage, individuals who are now aware of waste management issues seek additional information. Individuals may seek one-to-one exchanges with waste management professionals, political officials, or educators, or they may seek information about how they are involved in implementing a waste management initiative or an effective public policy. Making changes in required local waste management practices, such as mandatory recycling or yard trimmings disposal bans, will clearly stimulate interest, sometimes in the form of political opposition.

Using a variety of methods to explain the program may be helpful.

At this stage, program developers may need a variety of methods to explain the program. Voluntary programs need a strong emphasis on promotion. A mandatory program must clearly explain required behavior, as well as promote program benefits. Fact sheets prepared and distributed by state and federal regulatory agencies, local governments, university extension services, and waste-related business associations can provide clear and concise information for interested citizens. Making public speeches, offering tours of waste management facilities, creating exhibits for fairs, and preparing written material such as newsletters can help stimulate public interest in the program. Establishing and promoting a telephone hot line has been effective in a number of communities. In Onondaga County, New York, a promotion on two million milk cartons advertised a telephone hot line.

To promote newspaper recycling in San Francisco, residents received a paper grocery bag with newspapers delivered to homes. Printing on the bags gave instructions for recycling newspapers and a phone number for information. One survey concluded that information delivered to each residence, sometimes with utility bills, is a highly effective means of education.

Evaluation

At the evaluation stage, individuals decide whether to go along with the program. Even if the law requires specific behavior, achieving voluntary compliance is easier administratively and politically than strong enforcement. An easily understandable and convenient program will have the best chance of success.

Participation increases when program requirements are easy to follow.

Research has shown that for even well-promoted programs, initial participation is about 50 percent. Another third will participate as the program becomes established. Initial high participation rates should, therefore, not be expected.

Even for mandatory programs, convenience is a major factor in determining participation (see Figure 1-2). For example, the convenience of curbside pickup normally makes participation in waste management programs higher than for drop-off programs. As a result, some communities only provide drop-off service for yard trimmings, so that it becomes more convenient to not collect grass clippings or to home compost. A combined curbside and drop-off program may be the most convenient. At this stage (see Figure 1-3) education should stress what each citizen's role in the program is, their contribution to its success, and the most convenient level of participation.

Trial

The trial stage is decisive for participants.

By the fourth stage, individuals have decided to participate in the new activity. This is a crucial step for every program. If individuals try back yard composting or a volume-based system and encounter difficulty, they may choose not to adopt the desired conduct, and the program could lose political and public support.

By this stage in the educational program, everyone should have the information describing exactly what they are expected to do (see Figure 1-4). The community program must then provide the promised service in a highly reliable fashion. An adequately staffed and properly trained clearinghouse or hot line is a useful tool to answer questions and provide additional information. If appropriate, the hot line should be multilingual.

Figure 1-3
Example of Public Education Flyer

Be a holiday detective

. . . make your own reduction deductions!

Gifts that help others make a difference:

cloth napkins with matching tablecloth
cloth or string shopping bags
compost bin
gift certificates to resale shops
library card
lunch box/bag
party dishes that are durable and reusable
picnic basket cups, plates, & utensils
push mower
rechargeable alkaline batteries/charger
recycling bins
refillable pen & pencil set
reusable storage containers
stationery made from recycled paper

Gifts that save water and energy:

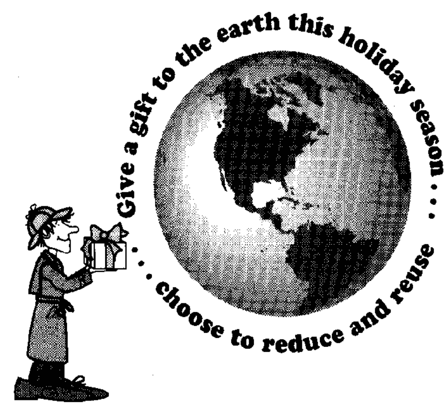
bus passes
compact fluorescent light bulbs
insulated bed pads for waterbeds
pool & hot tub blankets
waterheater blanket
water-saving faucets & showerheads

Living gifts:

house plants
potted evergreens
seeds for spring planting
your time—for childcare, cooking a meal, etc.

More reduction deductions:

make edible ornaments & write holiday greetings on cookies
make origami ornaments from used wrapping paper
place gifts in decorative tins, baskets, or bags
reuse greeting card picture for a post card or gift tag
reuse wrapping paper, boxes, ribbons, & bows
use old jewelry to make new jewelry, art, & decorations



These steps brought to you by...
The Wisconsin Waste Reduction Coalition:
Citizens for a Better Environment
City of West Allis
Godfrey Company
Keep Greater Milwaukee Beautiful
University of Wisconsin Cooperative Extension
Wisconsin Depts. of Natural Resources and Agriculture, Trade & Consumer Protection
Wisconsin Grocers Association
Wisconsin Merchants Federation

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Source: Wisconsin Department of Natural Resources

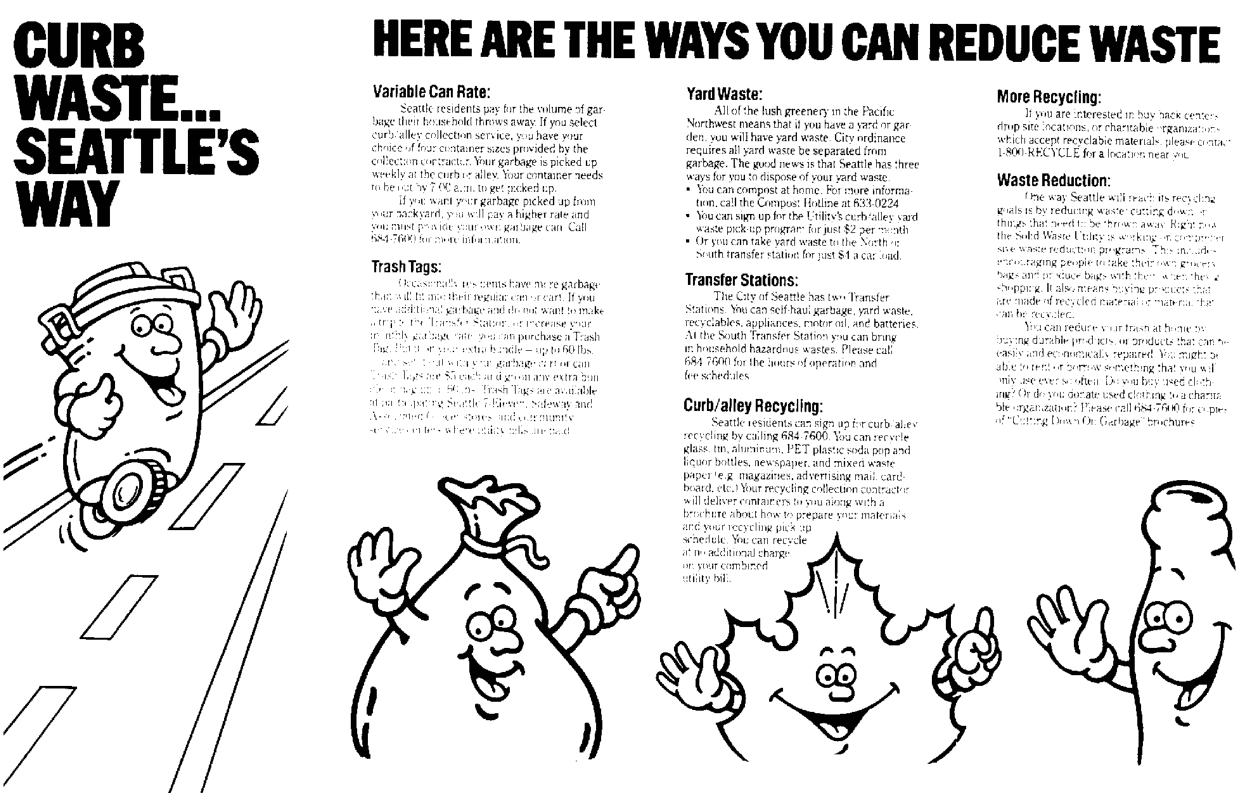
At the trial stage of a volunteer program, a pilot project can also help stimulate participation. Program organizers should assure citizens that the pilot project's goal is to evaluate various strategies, respond to public feedback, and make any changes required to improve program efficiency and reliability. Citizens may be more willing to try a project if they know that the project is short term and that any concerns they may have will be taken into account in developing a long-term effort. During the trial stage, public hearings may be helpful by giving citizens an opportunity to voice their opinions about the project. A focus group effort prior to initiation of the trial will help pinpoint important participant concerns and issues.

Adoption

Education should focus on reinforcing program participation at this stage.

If the education program has been well-planned and implemented, public support and participation should grow. Educational efforts at the fifth stage focus on providing citizens with positive feedback concerning program effectiveness (see Figure 1-5). A newsletter or other regular informational mailing can help inform citizens about the program's progress and any program changes. Community meetings can serve to reward and reinforce good behavior and answer questions. Local officials should be informed of program participation rates to generate political support for program budgets and personnel needs. At this stage, it can be helpful to target additional educational efforts at program nonparticipants.

Figure 1-4
Sample Education Program



CURB WASTE... SEATTLE'S WAY

HERE ARE THE WAYS YOU CAN REDUCE WASTE

Variable Can Rate:
Seattle residents pay for the volume of garbage their household throws away. If you select curb/alley collection service, you have your choice of four container sizes provided by the collection contractor. Your garbage is picked up weekly at the curb or alley. Your container needs to be out by 7:00 a.m. to get picked up.
If you want your garbage picked up from your backyard, you will pay a higher rate and you must provide your own garbage can. Call 684-7600 for more information.

Trash Tags:
Occasionally residents have more garbage than will fit into their regular can or cart. If you have additional garbage and do not want to make a trip to the Transfer Station, or increase your monthly garbage rate, you can purchase a Trash Tag. Put it on your extra bundle – up to 60 lbs. – and set it out with your garbage cart or can. Trash Tags are $5 each and go on any extra bundle weighing up to 60 lbs. Trash Tags are available at participating Seattle 7-Eleven, Safeway and Associated Grocer stores, and community service centers where utility bills are paid.

Yard Waste:
All of the lush greenery in the Pacific Northwest means that if you have a yard or garden, you will have yard waste. City ordinance requires all yard waste be separated from garbage. The good news is that Seattle has three ways for you to dispose of your yard waste.
- You can compost at home. For more information, call the Compost Hotline at 633-0224
- You can sign up for the Utility's curb/alley yard waste pick-up program for just $2 per month
- Or you can take yard waste to the North or South transfer station for just $4 a car load.

Transfer Stations:
The City of Seattle has two Transfer Stations. You can self-haul garbage, yard waste, recyclables, appliances, motor oil, and batteries. At the South Transfer Station you can bring in household hazardous wastes. Please call 684-7600 for the hours of operation and fee schedules.

Curb/alley Recycling:
Seattle residents can sign up for curb/alley recycling by calling 684-7600. You can recycle glass, tin, aluminum, PET plastic soda pop and liquor bottles, newspaper, and mixed waste paper (e.g. magazines, advertising mail, cardboard, etc.) Your recycling collection contractor will deliver containers to you along with a brochure about how to prepare your materials and your recycling pick up schedule. You can recycle at no additional charge on your combined utility bill.

More Recycling:
If you are interested in buy back centers, drop site locations, or charitable organizations which accept recyclable materials, please contact 1-800-RECYCLE for a location near you.

Waste Reduction:
One way Seattle will reach its recycling goals is by reducing waste: cutting down on things that need to be thrown away. Right now the Solid Waste Utility is working on comprehensive waste reduction programs. This includes encouraging people to take their own grocery bags and produce bags with them when they go shopping. It also means buying products that are made of recycled material or material that can be recycled.
You can reduce your trash at home by buying durable products, or products that can be easily and economically repaired. You might be able to rent or borrow something that you will only use ever so often. Do you buy used clothing? Or do you donate used clothing to a charitable organization? Please call 684-7600 for copies of "Cutting Down On Garbage" brochures.

Source: Seattle Solid Waste Utility

Maintenance

At the sixth stage, the program is up and running. Using a variety of intrinsic and extrinsic incentives will maintain and increase participation. Intrinsic incentives are largely informational. They are designed to induce citizens to perform the desired conduct for its own sake and because they provide a personal sense of well being and satisfaction. Extrinsic incentives are tangible rewards for performing desired conduct, such as reduced fees or monetary payments. A maintenance program may employ both types of incentives. Basic education must also continue.

INTRINSIC INCENTIVES

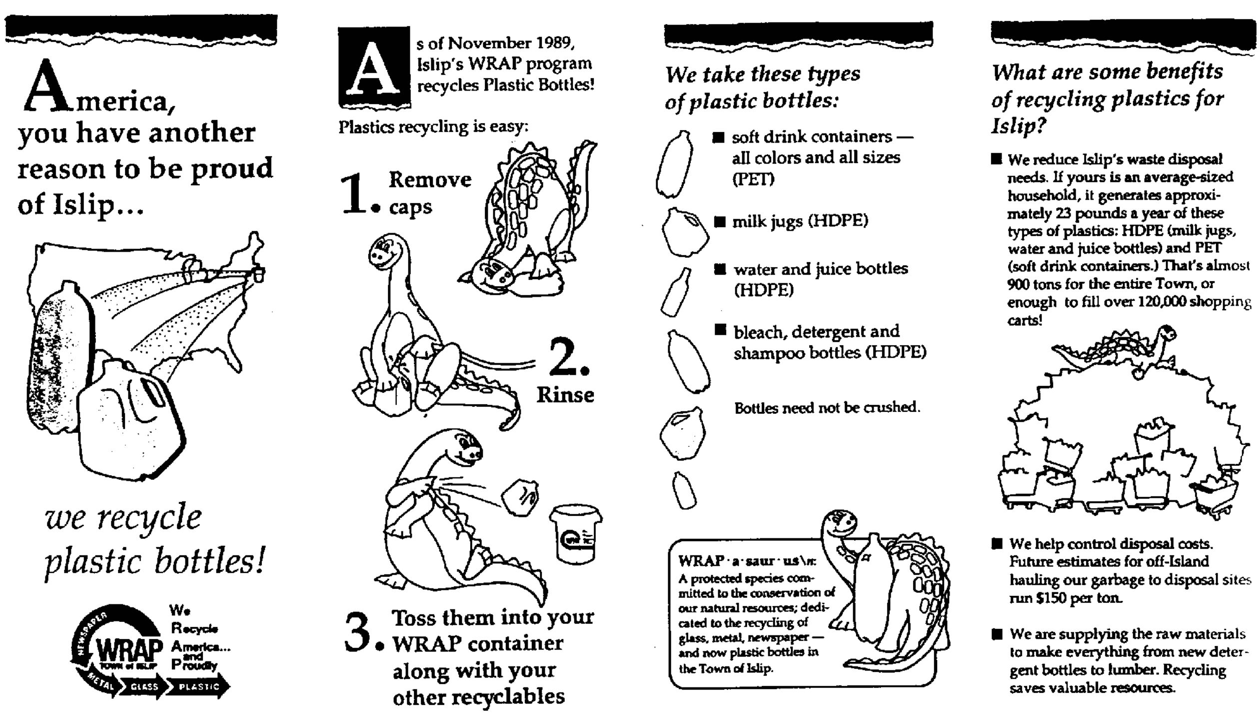
It is important for individuals to view participating as "the right thing to do."

Intrinsic incentives seek to support the desired behavior as the right thing to do. Some studies, for example, have shown that the ideals of frugality, resource conservation, and environmental protection over the long run were strong intrinsic motivators for those participating in recycling and reuse programs.

Issuing routine press releases and reports describing the progress of the program, providing awards for exemplary services, publishing newsletters for participating citizens and residences, and creating special events, such as “recycling week” or “master composter programs,” all provide positive support for community waste management activities. An aggressive school education program will provide intrinsic incentives over the long term.

Figure 1-5

Example of Material Encouraging Feedback on a Recycling Program



Source: WRAP (We Recycle America...and Proudly) Islip, New York

EXTRINSIC INCENTIVES

Extrinsic incentives provide direct rewards for desired activities. Volume-based fees are a form of extrinsic incentive: the smaller the waste volume generated, the less the generator must pay for waste management. Another well-known example of extrinsic incentives is the Rockford, Illinois, "cash for trash" campaign. This program involved weekly, random checks of a household's refuse with $1,000 rewards given to households that properly separated their recyclables from nonrecyclables.

Careful analysis of extrinsic incentives is important. For example, a volume-based fee system encourages both source reduction and recycling. But a volume-based collection system could actually reduce participation in recycling if minimum volumes are large. It is important that the public does not connect the desired activity only with a reward. If that happens, if the incentive program is terminated or changed, some people may stop or reduce participation in the program. The public must see the program as a way to promote proper conduct, not merely as a way to make money.

Participation can be encouraged through rewards and public recognition.

Nonmonetary social incentives can also be effective. Many communities use block captains or community leaders to help boost neighborhood participation. These local leaders remind neighbors that the problem is, in part, local and that local people can help solve it. Linking social and monetary incentives may also be possible. For example, the proceeds from a neighborhood-run collection center could help support a neighborhood project or local recreational programs.

Organizers should carefully consider extrinsic incentives. Payback in terms of increased participation in the program and improved awareness and understanding of issues should offset the cost of the incentive. The extrinsic incentive should always be seen as an adjunct to the program, not the sole reason for participating. Extrinsic incentives can help get people interested in participating while intrinsic values are being developed through education.

THE PUBLIC INVOLVEMENT PLAN

Public involvement is too frequently confined to the facility siting process (see Chapter 2). Participation of local residents should begin earlier, when program developers are deciding which overall waste management strategy will best meet the community's economic and environmental needs. The strategy should consider source reduction and other options in addition to the facility being proposed. Allowing public involvement only at the facility-siting stage, and not before, may engender public opposition; residents may view the siting process as a *fait accompli*, because other decisions (which waste management option to use) were made without their participation.

Public involvement should start early, before the siting process begins.

Choosing a site without input from residents and then weathering intense opposition has been called the "decide-announce-defend" strategy. Although this strategy has been used extensively in the past, the increasing sophistication of groups opposed to certain waste management alternatives makes this approach more difficult. The public is demanding meaningful participation in making waste management decisions. But the public must also accept responsibility for its role in implementing sound and cost effective waste management solutions.

THE ISSUE EVOLUTION-EDUCATIONAL INTERVENTION (IEEI) MODEL

Although some communities still use the "decide-announce-defend" strategy, many now realize that, while there will probably always be opposition to proposed waste management strategies, investigating alternatives and building a consensus are likely to result in more efficient decision making.

Developing a written plan for seeking public involvement is important. Written procedures help insure the inclusion of all important interests and legal requirements. The plan will show involved citizens and groups at which points in the process they can express opinions and how to be most effective in communicating their views. A written, publicly available plan lends credibility to the program.

The “Issue Evolution-Educational Intervention” (IEEI) model provides public involvement throughout the decision-making process. It comprises an eight-stage process for developing and implementing public policy:

Stage 1—Concern	Stage 5—Consequences
Stage 2—Involvement	Stage 6—Choice
Stage 3—Issue Resolution	Stage 7—Implementation
Stage 4—Alternatives	Stage 8—Evaluation

Following the IEEI Model helps elicit public participation.

The IEEI process ensures that the public will have a meaningful voice in deciding how best to manage solid waste. The process is not simple and requires a commitment from the community of time and resources. Each of the stages is briefly discussed below (also see Figure 1-6).

1. **Concern:** In the first IEEI stage, an event puts waste management on the public agenda. Perhaps the local landfill is nearing capacity and is about to close. Perhaps the legislature has just enacted a mandatory recycling bill. The public begins to ask questions.

   At this stage, a procedure for providing accurate, reliable information to the public is important. Eliminating misconceptions and establishing a firm educational base for public discussion is the key. County and university extension offices, governmental associations, and regulatory agencies can provide information. Education programs should target local officials, as well as the public. Showing concern and a willingness to take proper action is most important. A focus group can help define important public issues. Community service organizations can provide a forum for discussion.

2. **Involvement:** As discussion of the issue begins, regulatory officials, persons from neighboring communities, local waste management experts, environmental and business groups, and others should be encouraged to participate. Bringing representatives of interest groups together and providing a forum for communication is a valuable activity. Cultural diversity is another consideration when seeking input from the broadest possible spectrum of the community.

3. **Issue Resolution:** Interest groups should make clear their points of agreement and disagreement. The various groups should then attempt to understand and resolve points of conflict. Determining what people can agree on is also important. All parties need to understand the motivation and circumstances of the other community interests in the process.

4. **Alternatives:** The participants should develop a list of available alternatives; the list should include taking no action. Each alternative should have a list of potential sites for facilities.

   At this stage participants should use the same criteria to analyze comparative economics, environmental impacts, and other aspects of each alternative. Each interest group should scrutinize carefully the analyses prepared by all others. Results of analyses of various alternatives should be communicated to local officials and input sought from the public and others.

5. **Consequences:** Involved parties should then determine and compare the economic and environmental effects of each alternative. They should

also evaluate consequences in light of community resources and goals. The public must understand the results of choosing one alternative over another. All involved interest groups should acknowledge the benefits and costs associated with each alternative.

6. **Choice:** At this stage, the decision-making body must decide which alternative or group of alternatives to implement. In addition to publicizing the chosen alternative or alternatives, the decision makers should clearly communicate the reasons behind each choice by explaining the necessary tradeoffs, the efforts made to consider the interests of each affected group, and the anticipated impact of the chosen alternative or alternatives on the community.

   Not all interest groups will support the chosen alternative or alternatives. Some may oppose the option(s) chosen and seek to force reconsideration of other alternatives through legal and political challenges. The process outlined here does not guarantee success, but it will help develop a broad community consensus, enabling the community to better withstand legal and political challenges.

7. **Implementation:** At this stage, the decision makers should describe the steps necessary to implement the chosen strategy. They should also try to mitigate potential adverse impacts which the chosen alternative or alternatives may have on relevant interest groups. Chapter 2 discusses this issue in more detail.

8. **Evaluation:** The community should continually evaluate the model and solicit input from affected groups. The impact of decisions should be communicated routinely to the public and to local officials. Ongoing evaluation helps provide an information base for making future waste management decisions. Existing programs will continually improve if they respond to changing conditions and public input.

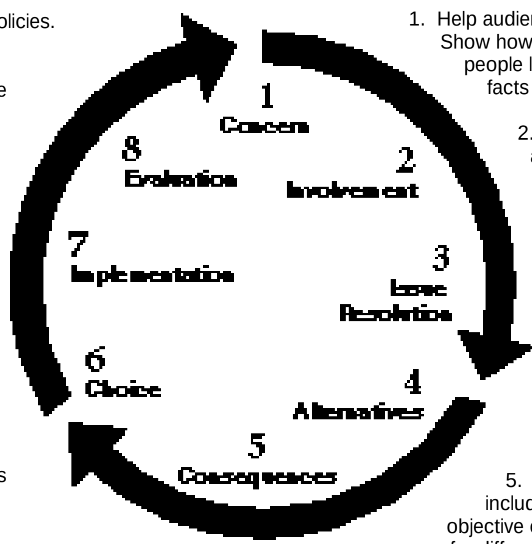
Figure 1-6

Issue Evolution/Educational Intervention Model

8. Help monitor and evaluate policies. Inform people about formal evaluations and their results. Help stakeholders participate in formal evaluations.

7. Inform people about new policies and how they and others are affected. Explain how and why the polices were enacted. Help people understand how to ensure proper implementation.

6. Explain where and when decisions will be made and who will make them. Explain how decisions are made and influenced. Enable audiences to design realistic strategies.



1. Help audiences understand existing conditions. Show how different groups are affected. Help people look beyond symptoms. Help separate facts and myths and clarify values.

2. Identify decision makers and others affected. Stimulate communication among decision makers, supporters, and opponents.

3. Help clarify goals or interests. Help understand goals or interests of others and points of disagreement. Help get the issue on the agenda.

4. Identify alternatives, reflecting all sides of the issue and including "doing nothing." Help locate or invent additional alternatives.

5. Help predict and analyze consequences, including impacts on values as well as objective conditions. Show how consequences vary for different groups. Facilitate comparison of alternatives.

House, V., "Issue Evolution and Educational intervention," *Working With Our Publics, Module 6: Education for Public Decisions,* 1988

REFERENCES

De Young, R. 1984. "Motivating People to Recycle: The Use of Incentives," *Resource Recycling* (May-June).

Folz, D., and Hazlett, J. 1990. "A National Survey of Local Government Recycling Programs," *Resource Recycling* (December).

Hansen, Z. 1983. *Sensible Publicity, A Guide.* Ramsey County Health Department, 1910 W. County Rd. B., Roseville, MN (November).

House, V. 1988. "Issue Evolution and Educational Intervention," *Working With Our Publics, Module 6: Education for Public Decisions.* North Carolina Agricultural Extension Service and Department of Adult and Community College Education, North Carolina State University, Raleigh, NC.

Kashmanian, R., et al. 1990. "Source Reduction and Recycling: Promotion Strategies," *Resource Recycling* (July).

Lueck, G. W. 1990. "Elementary Lessons in Garbage Appreciation," *Waste Age* (September).

O'Rorke, M., and Hely, B. 1989. "Creating a Public Information Program that Works," *Resource Recycling* (May-June).

Rickmerss-Skislak, T. 1987. "How to 'Sell' Recycling Programs," *Biocycle* (October).

2 ❖

FACILITY SITING AND PERMITTING

Facility siting and permitting have become the most contentious and difficult aspects of the solid waste management process. Public officials are challenged to find sites that are technically and environmentally sound and socially acceptable. The intense political conflicts in local communities center on important questions of the appropriate use of technology, acceptable levels of risk, and the distribution of decision-making power in a democratic society.

This chapter summarizes the detailed discussion of facility siting issues set forth in the U.S. Environmental Protection Agency document *Sites for Our Solid Waste: A Guidebook for Effective Public Involvement*. The USEPA siting guide provides a detailed procedure for effectively siting a solid waste facility. Readers needing more detail than this guidebook provides are encouraged to thoroughly review *Sites for Our Solid Waste.*

This chapter also briefly addresses permitting solid waste management facilities. Although specific regulatory requirements for proposed alternatives vary from state to state, there are general guidelines that should be followed to successfully implement a project. A proper approach to securing permits is essential, since the decision to seek a facility permit requires a significant expenditure of community resources and time.

From: Decision Maker's Guide to Solid Waste Management, Volume II, (EPA 530-R-95-023), 1995. Project Co-Directors: Philip R. O'Leary and Patrick W. Walsh, Solid and Hazardous Waste Education Center, University of Wisconsin-Madison/Extension. This document was supported in part by the Office of Solid Waste (5306), Municipal and Industrial Solid Waste Division, U.S. Environmental Protection Agency under grant number CX-817119-01. The material in this document has been subject to Agency technical and policy review and approved for publication as an EPA report. Mention of trade names, products, or services does not convey, and should not be interpreted as conveying, official EPA approval, endorsement, or recommendation.

2 HIGHLIGHTS

Facility siting and permitting is a potentially contentious process. (p. 2-1)	Facility siting and permitting has become the most contentious and difficult part of the solid waste management process. Finding sites that are both technically feasible *and* environmentally and socially acceptable can be difficult. Many communities have experienced intense political conflicts centered on uses of technology, acceptable levels of risk, and distribution of decision-making power.
When creating a siting strategy, consider lessons from experience. (p. 2-4)	• Use the political/technical expertise of public officials and citizens. • Consult with the relevant public sector at every stage. • Provide accurate, useful information about all aspects of the project, including risks, and maintain a dialogue with the public. • Keep the process flexible and negotiable. • Use only accurate and truthful information (written or spoken) at all times. • Successful siting may involve compensation for real or perceived local impacts.
Developing a public involvement plan early is crucial. (p. 2-4 — 2-7)	Behind-the-scenes decision making, called the “decide-announce-defend” model, is likely to be unacceptable today. The public must be given an opportunity to participate in every phase of the siting process. Developing a public involvement plan is crucial; Table 2-1 outlines the elements of such a plan. Clearly identifying the different segments (or publics) in the community is the first step. The reasons people get involved include their proximity to possible sites, economic impact, usefulness of the facility, personal values, legal mandates. Program organizers and officials should inform the public of the following: • possible site-related and broadly based socioeconomic issues • possible consequences of choosing not to have a facility • how individuals can get involved (in what types of tasks and projects) • how to get information about the proposed project and how to contact relevant officials • how to make their opinions known to decision makers.
Several techniques for involving the public are available. (p. 2-8 — 2-10)	Public involvement should be a dialogue—two-way communication in which clearly stated and objective information is provided and the public's concerns, opinions, and ideas are solicited and considered. Table 2-3 describes major techniques for communicating with the public; Table 2-4 provides techniques for soliciting public input.
Communicating risk is essential. (p. 2-8 — 2-12)	Risk communication emphasizes a two-way information exchange in which risk managers listen to and learn from the public. Table 2-5 presents USEPA's “Seven Cardinal Rules of Risk Communication.” Risk managers should provide accurate, objective information early in the process so citizens can form accurate conclusions about the proposed project when risk-related questions arise. Some risk-related cautions include: • Do not assume that a risk management program will solve all siting-related problems. • Be aware that developing an effective risk-communication program is not easy. • Do not assume that developing a risk-communication plan ensures community acceptance of the risks (real or perceived) associated with the proposed project.

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Follow these six steps when developing a risk communication plan.

(p. 2-11 — 2-12)

1. Identify the risk communication objectives for each step in the siting process (see Table 2-6).
2. Know what information should be exchanged at each stage. A "risk management checklist" is provided in Table 2-7.
3. Identify the groups with whom information must be exchanged.
4. Develop appropriate risk messages for each targeted audience.
5. Identify the appropriate channels for communicating risks to various segments of the public.
6. Evaluate your efforts and modify the approach as needed.

Building credibility for technical information is essential.

(p. 2-13)

Public mistrust of technical information is a major siting issue. Communicating accurate technical information is crucial. The following can help build credibility:

- Anticipate issues likely to emerge.
- Involve the public in planning and in selecting technical consultants.
- Use an "outside," jointly chosen impartial expert to review technical studies.
- Present technical information in language for nontechnical audiences.
- Openly discuss uncertainties and assumptions.

Address possible negative impacts (real or perceived) early in project development.

(p. 2-14)

Common concerns about solid waste facilities that may require some form of mitigation include process issues, health risks, environmental issues, and local impacts. Basic steps in planning for impacts include the following:

1. Outline a decision-making process for mitigation issues.
2. Identify issues that are likely to arise.
3. Identify concerned segments of the public for each issue.
4. Identify forums for resolving mitigation issues with those affected.
5. Integrate required mitigation activities into the public involvement plan.

The permitting process requires knowledge and technical expertise.

(p. 2-15 — 2-17)

Federal, state, and local governments enact laws to ensure that proposed projects meet minimum technical and legal criteria. The number of permits required depends on the type of facility being planned and local, state, and federal laws. Permitting ensures that a proposed project will not unduly affect the health and environment of the community and that it will be consistent with local public policy.

After an internal review that includes public input, the reviewing agency must produce a written decision awarding a permit or disallowing the project.

It is crucial to accurately determine which permits will be required for the proposed facility; a permitting oversight can paralyze a project. To determine permit needs consult with appropriate local, state, and federal agencies, such as state/tribe and local environmental planning agencies.

2 FACILITY SITING AND PERMITTING

THE SITING PROCESS

Public involvement in the siting process is crucial to a program's success.

The traditional siting process, sometimes called the "decide-announce-defend" model, placed decision-making power in the hands of a few key individuals. But citizens have demonstrated that they will not accept behind-the-scenes decisions on solid waste management, and a new approach to siting is being tried around the country; it consists of three related phases—planning, site selection and facility design, and implementation. Any stage of the siting process may be subjected to intense public debate (see Figure 2-1).

Creating a Siting Strategy

Most experts agree that no perfect siting model exists. Even so, lessons from successful sitings do offer insight into which strategies should be pursued and how public officials can resolve particularly difficult issues. The following lessons have been drawn from actual sitings.

Consider these tips from previous siting experiences.

- Successful siting efforts require the political and technical expertise of both public officials and citizens.
- Appropriate sectors of the public should be consulted at every stage of the decision-making process.
- Successful sitings require an informed and thorough analysis; a good risk-communication program establishes an exchange of information among various participants.
- Credible and accurate technical information is crucial to resolving conflicts in the siting process.
- The siting process must be flexible; all characteristics are negotiable.
- Careful planning and effective management are essential for successful siting.
- The state plays an important role in supporting an effective siting process.
- All information, written or oral, must be honest at all times.
- Siting a waste management facility must be only one part of an integrated waste management strategy. No one facility is the answer.
- Siting may involve compensation for real and perceived local impacts.

Who Is the Public?

The first step in designing a public involvement program is to stop and think: Who is the public? The public is not a single entity—many interests and

Figure 2-1

The Three-Phase Siting Framework

Phase I: Planning	
Identifying the problem ▼	Recognizing the growing waste stream, rising costs, and capacity shortfall.
Designing the siting strategy ▼	Planning and integrating public involvement, risk communication, mitigation and evaluation activities.
Assessing alternatives ▼	Researching, debating, and choosing among the options: recycling, source reduction, incineration, and land disposal.
Choosing site feasibility criteria ▼	Studying population densities, hydro-geological conditions, and socioeconomic characteristics.
Phase II: Site selection and facility design	
Selecting the site ▼	Performing initial site screening and designation; acquiring land; conducting permit procedures; performing initial environmental review; developing environmental impact statement if necessary.
Designing the facility ▼	Choosing technologies, dimensions, safety characteristics, restrictions, mitigation plans, compensation arrangements, and construction.
Phase III: Implementation	
Operation ▼	Monitoring incoming waste; managing waste disposal; performing visual and lab testing; controlling noise, litter and odor.
Management ▼	Monitoring operations and safety features; performing random testing of waste; enforcing permit conditions.
Closing and future land uses	Closing and securing the facility; deciding on future land uses; and performing continued monitoring.

USEPA, *Sites for Our Solid Waste: A Guidebook for Effective Public Involvement,* 1990

groups make up the various segments of the public. Some interests or groups are well established, such as professional associations, political parties, churches, some social groups, and home owners' associations. Others are newly established because their members have a common, continuing interest in the proposed community action.

Community members might become involved in siting for several reasons:

- **Proximity:** People who live in the immediate vicinity of a facility may feel that their health and environment are threatened.

- **Economic impact:** People are concerned about effects waste problems might have on municipal services and on economic development.
- **Users:** Prospective users of a facility may become involved if the use is threatened.
- **Social/environmental issues:** People may become involved in siting as a result of larger community issues such as air and water pollution or a desire to force a community to initiate waste reduction or recycling programs.
- **Values:** When questions of health or safety reach a high level of polarization, citizens often discuss waste issues in terms of ethics or moral values.
- **Legal mandates:** Governmental agencies at the local and state levels play the most significant roles in facility sitings; however, federal agencies may become participants depending upon the issues involved.

Different segments of the public have different rates of involvement in waste management programs.

The various segments of the public will have different levels of involvement based on different roles, technical expertise, and willingness to commit time, energy, and in some cases money. Different types of public involvement may be necessary to reach different groups (see Figure 2-2).

Involvement also differs over time.

Different kinds of public involvement may be required depending upon the group. A steering committee or technical advisory committee can be useful in helping to design studies that need to be conducted, perform technical reviews, rank consulting firms, and review rankings for sites. Because individuals and groups will differ in the amount of time and energy they are willing to invest, a variety of opportunities for public participation should be offered to accommodate varying levels of interest and expertise.

The size and composition of the involved public will also change over time. Different groups and interests will be represented at different stages of the siting process. The size of the interested public for a particular issue will increase with controversy, and public involvement will increase as the siting process progresses.

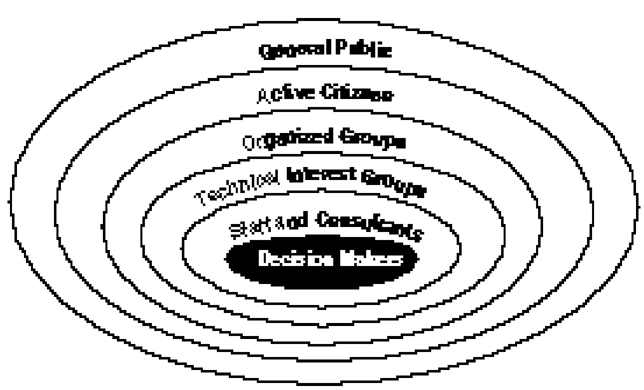
In developing a siting program, officials have several obligations to the general public:

Officials have several obligations to the public.

- Inform the public of the likely consequences of a proposed action, so that people can choose whether to participate; the consequences should encompass site-related issues and more broadly based socioeconomic issues.

Figure 2-2

Levels of Involvement by Various Segments of the Public



USEPA, *Sites for Our Solid Waste: A Guidebook for Effective Public Involvement,* 1990

- Inform the public of the consequences of not taking a proposed action.
- Tell people how they can participate so those who are interested can get involved.
- Provide all segments of the public equal access to information and to decision makers.
- Seek the full spectrum of opinions within the community.

Including the Public in the Process

Experience from successful sitings shows that involving the public is as important to success as performing good technical studies. Effective public involvement requires integrating public concerns and values at every stage of the siting process. Token participation will not buy credibility and may even offend the public more than if there had been no consultation at all.

Developing a plan for involving the public is advisable.

Most experienced practitioners prepare a formal public involvement plan at the beginning of any decision-making process. There are three major reasons for developing a public involvement plan:

1. Preparing a plan forces careful analysis of how the public fits into the siting process.
2. Preparing a plan provides a mechanism for consultation among the various agencies and entities that have a stake in the program.
3. A plan communicates to the public what to expect, helping to establish the credibility of the sponsoring agencies.

When developing a plan, identify organized groups likely to have an interest in the siting issue. Develop the plan using expertise from a variety of departments and agencies, including the one siting the solid waste facility. Also, involve private-sector representatives who can or will be affected by the siting. Have one member designated as the leader of the group to help move people through the thought process for developing the plan.

The plan should ultimately be a summary of the group's thinking, rather than a plan imposed on the group. Table 2-1 sets forth the elements of a public involvement plan. The plan can vary in length, but it should be a flexible document that will provide a structure for analyzing the requirements of the situation. The objectives of the plan (see Table 2-2) can be used to measure the adequacy of preliminary drafts. The plan must be dynamic and be updated as circumstances change. Planning should include periodic review to evaluate program effectiveness.

Table 2-1
The Elements of a Public Involvement Plan

- Describe any early consultation (e.g. interviews with interest group leaders) that led to the development of the plan.
- Describe the major issues likely to emerge in the course of the siting process.
- Estimate the level of public interest likely to be generated by the decision under consideration.
- List the agencies, groups and key individuals most likely to be interested in the siting process.
- List the major stages in the siting process.
- Outline a sequential plan of public involvement activities for each stage in the siting process.
- List key points when the public involvement plan will be reviewed, and if necessary, revised.
- Provide, for internal discussion, a staff and budget estimate and an analysis of the support services required to implement the plan.

USEPA, *Sites for Our Solid Waste: A Guidebook for Effective Public Involvement,* 1990

Techniques for Involving the Public

Establishing two-way communication with the public is crucial.

Public involvement is a dialogue, a two-way communication that involves both getting information out to the public and getting back from the public ideas, issues, and concerns. For convenience, it is easier to divide the public involvement process into two categories: information techniques (getting information to the public) and participation techniques (getting information from the public). Some major techniques for communicating to the public are described in Table 2-3.

Once the public has been informed, the next step is to provide forums or mechanisms by which the public can express issues or concerns. Table 2-4 provides a number of techniques available for seeking public input. Advantages and disadvantages of each technique are described.

No one public involvement program meets the needs of all circumstances. It is important to clearly define the goals of public participation and which segments of the public should be addressed at various stages in the siting process.

In developing a public involvement plan, a few cautions should be observed:

- Advisory groups can be very helpful, but be aware of their limitations—members must be certain about the group's charter and should not spend so much time agreeing on procedures that people concerned with substance become alienated.
- Public information materials should provide useful, objective information. They should not be public relation pieces aimed at selling a particular point of view.
- Play it straight with the media. Provide all information objectively and factually.
- Get back to people promptly in response to comments. Without feedback, you provide no rewards to stimulate further public participation.
- Never surprise elected officials. Never announce a site has been selected in an official's district without briefing him or her first.

Communicating Risks More Effectively

Successful risk communication involves listening to and learning from the public.

Risk communication is the exchange of information between risk managers and the general public about a particular issue. Risk communication emphasizes a two-way information exchange in which risk managers also listen and learn from the public. This information exchange is crucial to a responsive, participatory siting process.

Table 2-2

The Objectives of a Public Involvement Plan

- Include enough detail so that everyone involved in implementing the plan knows what he or she is expected to do, and when.
- Include enough detail to permit development of budget, staff, and schedule estimates.
- Allow agency management or policy boards to assess the adequacy of the activities planned in relationship to the anticipated public interest.
- Clearly communicate to the public how and when they will have opportunities to participate.

USEPA, *Sites for Our Solid Waste: A Guidebook for Effective Public Involvement,* 1990

Table 2-3

Public Information Techniques

Technique	Features	Advantages	Disadvantages
Briefings	Personal visit or phone call to key officials or group leaders to announce a decision, provide background information, or answer questions.	Provide background information. Determine reactions before an issue "goes public." Alert key people to issues that may affect them.	Requires time.
Feature stories	In-depth story about the siting study in newspapers or on radio and television.	Provide detailed information to stimulate interest in the siting study, particularly at key junctures such as evaluating alternative sites or selecting a preferred site. Often used prior to public meetings to stimulate interest.	Newspaper will present the story as editor sees fit—project proponent has no control over how the story is presented, except to provide full information.
Mailing out key technical reports or environmental documents	Mailing technical studies or environmental reports to other agencies and leaders of organized groups or interests.	Provides full and detailed information to people who are most interested. Often increases credibility of studies because they are fully visible.	Costs money to print and mail. Some people may not even read the reports.
News conferences	Brief presentation to reporters, followed by question-and-answer period, often accompanied by handouts of presenter's comments.	Stimulate media interest in a story. Direct quotes often appear in television/radio. Might draw attention to an announcement or generate interest in public meetings.	Reporters will only come if the announcement/ presentation is newsworthy. Cannot control how the story is presented, although some direct quotes are likely.
Newsletters	Brief description of what is going on in the siting study, usually issued at key intervals for all people who have shown an interest in the study.	Provide more information than can be presented through the media to those who are most interested. Often used to provide information prior to public meetings or key decision points. Also maintain visibility during extended technical studies.	Requires staff time and costs money to prepare. print, and mail. Stories must be objective and credible or people will react to newsletters as if they were propaganda.
Newspaper inserts	Much like a newsletter, but distributed as an insert in a newspaper.	Reach the entire community with important information such as project need and alternative sites being considered. Is one of the few mechanisms for reaching everyone in the community through which you can tell the story your way.	Requires staff time to prepare insert, and distribution costs money. Must be prepared to newspaper's layout specifications. Potential negative reaction to use of public funds for this purpose exists.
News releases	A short announcement or news story issued to the media to get interest in media coverage of the story.	May stimulate interest from the media. Useful for announcing meetings or major decisions or as background material for future media stories.	May be ignored or not read. Cannot control how the information is used.
Paid advertisements	Advertising space purchased in newspapers or on radio or television.	Effective for announcing meetings or key decisions. Story presented the way you want.	Advertising space can be costly. Radio and television may entail expensive production costs to prepare the ad. Potential negative reaction to use of public funds for this purpose exists.
Presentations to civic and technical groups	Deliver presentations, enhanced with slides or viewgraphs, to key community groups.	Stimulates communication with key community groups. Can also provide indepth feedback.	Few disadvantages, except some groups may be hostile.
Press kits	A packet of information distributed to reporters.	Stimulates media interest in the story. Provides background information which reporters use for future stories.	Has few disadvantages, except may be ignored. Cannot control how the information is used.
Public service announcements	Short announcement provided free of charge by radio and television stations as part of their public service obligations.	Useful for making announcements such as for public meetings.	Many organizations compete for the same space. Story may not be aired or may be aired at hours when there are few listeners.

USEPA, *Sites for Our Solid Waste: A Guidebook for Effective Public Involvement* 1990

Table 2-4

Participation Techniques

Technique	Features	Advantages	Disadvantages
Advisory groups/task forces	A group of representatives of key interested parties is established. May be a policy technical or citizen advisory group.	Provide oversight to the siting process. Promote communication between key constituencies. Anticipate public reaction to publications or decisions. Provide a forum for reaching consensus.	Potential for controversy exists if "advisory" recommendations are not followed. Requires substantial committment of staff time to provide support to committees.
Focus groups	Small discussion groups established to give "typical" reactions of the public. Conducted by professional facilitator. Several sessions may be conducted with different groups.	Provide in-depth reaction to publications ideas or decisions. Good for predicting emotional reactions.	Get reactions, but no knowledge of how many people share those reactions. Might be perceived as an effort to manipulate the public.
Hotline	Widely advertised phone number handles questions or provides centralized source of information about the siting.	Gives people a sense that they know whom to call. Provides a one-step service of information. Can handle two-way communication.	Is only as effective as the person answering the hotline phone. Can be expensive.
Interviews	Face-to-face interviews with key officials interest group leaders or key individuals.	Can be used to anticipate issues or anticipate the reactions of groups to a decision. Can also be used to assess "how are we doing."	Requires extensive staff time.
Hearings	Formal meetings where people present formal speeches and presentations.	May be used as a "wrap-up meeting" prior to final decision. Useful in preparing a formal public record for legal purposes.	Exaggerates differences. Does not permit dialogue. Requires time to organize and conduct.
Meetings	Less formal meetings for people to present positions, ask questions, and so forth.	Highly legitimate form for the public to be heard on issues. May be structured to permit small group interaction—anyone can speak.	Unless small-group discussion format is used, permits only limited dialogue. May get exaggerated positions or grandstanding. Requires staff time to prepare for meeting.
Workshops	Smaller meetings designed to complete a task.	Very useful for tasks such as identifying siting criteria or evaluating sites. Permits maximum use of dialogue, good for consensus-building.	Limitations on size may require several workshops in different locations. Is inappropriate for large audiences. Requires staff time for multiple meetings.
Plebiscite	City-wide election to decide where or whether a facility should be built.	Provides a definite, and usually binding, decision on where or whether a facility should be built.	Campaign is expensive and time-consuming. General public may be susceptible to uninformed emotional arguments.
Polls	Carefully designed questions are asked of a portion of the public selected as representative of public opinion.	Provides a quantitative estimate of general public opinion.	Provides a "snapshot" of public opinion at a point in time—opinion may change. Assumes all viewpoints count equally in decision. Costs money and must be professionally designed.

USEPA, *Sites for Our Solid Waste: A Guidebook for Effective Public Involvement* 1990

Inform the public honestly about potential risks and precautions.

The primary goal of risk communication in the siting process is to help participants, and even observers who may become participants, make informed contributions to the decision-making process. As stated by the National Research Council, "Risk communication is successful only to the extent that it raises the level of understanding of relevant issues or actions and satisfies those involved that are adequately informed within the limits of available knowledge" (USEPA 1990).

In siting solid waste facilities, communicators need to tell the public what is known about environmental and health risks associated with the facility and what precautions are being taken to manage those risks.

Officials need to consider these precautions to avoid pitfalls in developing a risk-communication program:

1. Do not assume that developing a risk-management communication program will solve all the problems with the siting process.
2. Do not assume that developing an effective risk-communication program is an easy task.
3. Do not assume that developing a risk-communication program guarantees public acceptance of the risks.

Make information easily accessible to the public.

Developing a risk-communication program at the beginning of the siting process will increase the likelihood that the public has access to useful information when it is most needed. USEPA's Seven Cardinal Rules of Risk Communication provides a guide (see Table 2-5). Risk communication should be integrated into the public involvement plan. Keep a written plan or record of risk-communication activities to provide a data base for evaluating the effectiveness of the program.

The six steps to follow in developing a risk-communication program are as follows:

1. Identify the risk-communication objectives for each step in the siting process (see Table 2-6).
2. Determine the information exchange needed to complete each step in the siting process. Table 2-7 is a typical risk message checklist.
3. Identify the groups with whom information must be exchanged.

Table 2-5

Seven Cardinal Rules of Risk Communication

There are no easy prescriptions for successful risk communication. However, those who have studied and participated in recent debates about risk generally agree on seven cardinal rules. These rules apply equally well to the public and private sectors. Although many of the rules may seem obvious, they are continually and consistently violated in practice. Thus, a useful way to read these rules is to focus on why they are frequently not followed.

1. Accept and involve the public as a legitimate partner.
2. Plan carefully and evaluate your efforts.
3. Listen to the public's specific concerns.
4. Be honest, frank and open.
5. Coordinate and collaborate with other credible sources.
6. Meet the needs of the media.
7. Speak clearly and with compassion.

USEPA, *Seven Cardinal Rules of Risk Communication,* 1988

4. Develop appropriate risk messages for each targeted audience. Some key characteristics of public risk perceptions are set forth in Table 2-8.
5. Identify the appropriate channels for communicating risks to various segments of the public.
6. Evaluate efforts and modify approach as needed.

Table 2-6

Examples of Risk Communication Objectives

- Include enough detail so that everyone involved in implementing the plan knows what he or she is expected to do, and when.
- Include enough detail to permit development of budget and staff and to schedule estimates.
- Allow agency management or policy boards to assess the adequacy of the activities planned in relationship to the anticipated public interest.
- Clearly communicate to the public how and when they will have opportunities to participate.

USEPA, *Sites for Our Solid Waste: A Guidebook for Effective Public Involvement,* 1990

Table 2-7

Risk Management Checklist

Information about the nature of risks

1. What are the hazards of concern?
2. What is the probability of exposure to each hazard?
3. What is the distribution of exposure?
4. What is the probability of each type of harm from a given exposure to each hazard?
5. What are the sensitivities of different populations to each hazard?
6. How do exposures interact with exposures to other hazards?
7. What are the characteristics of the hazard?
8. What is the total population risk?

Information about the nature of benefits

1. What are the benefits associated with the hazard?
2. What is the probability that the projected benefit will actually follow the activity in question?
3. What are the characteristics of the benefits?
4. Who benefits and in what way?
5. How many people benefit and how long do benefits last?
6. Which groups get disproportionate shares of the benefits?
7. What is the total benefit?

Information about alternatives

1. What are the alternatives to the hazard in question?
2. What is the effectiveness of each alternative?
3. What are the risks and benefits of each alternative and of not acting?
4. What are the costs and benefits of each alternative and how are they distributed?

Uncertainties in knowledge about risks

1. What are the weaknesses of available data?
2. What are the assumptions on which estimates are based?
3. How sensitive are the estimates to changes in assumptions?
4. How sensitive is the decision to changes in the estimates?
5. What other risk and risk control assessments have been made and why are they different from those now being offered?

Information about management

1. Who is responsible for the decision?
2. What issues have legal importance?

Source: National Research Council, *Improving Risk Communication,* 1989

Building Credibility for Technical Information

Public skepticism about technical information must be addressed.

Public mistrust of technical information is a major siting issue. Communicating accurate technical information is a crucial part of the process. Two of the most important goals for risk communicators are building the credibility of technical information in the eyes of the public and improving the relevance of technical studies to public concerns.

People assume that once an issue is controversial, all sides are using technical information in an effort to "win," or to convince the public. Mistrust seems to be characteristic of political conflict. If the credibility of technical information is to be protected and maintained throughout the siting process, steps must be taken early in the siting process before a situation becomes controversial. If a siting issue becomes polarized, and program developers are seen as advocates, restoring credibility is difficult. When a final choice is made, advocacy is expected. The following can help build credibility for technical information:

- Anticipate the issues that will emerge.
- Solicit public participation in developing the study plan.
- Validate methodological assumptions.
- Invite public involvement in selecting consultants.
- Provide technical assistance to the public.
- Use an outside jointly chosen impartial expert to review technical studies.

Table 2-8

Key Characteristics of Public Risk Perceptions

- *Voluntary risks are accepted more readily than those that are imposed.* Communities react angrily if they feel coerced into accepting a new solid waste facility. This reaction against the siting process and the agency personnel ultimately leads to a greater perception of risk.
- *Risks under individual control are accepted more readily than those under government control.* In contrast to a risk such as driving without a seat belt, neighbors of potential sites have little control over risks from the site other than the extreme case of selling their homes and moving elsewhere.
- *Risks that seem fair are more acceptable than those that seem unfair.* If the benefits and negative impacts are spread unevenly over the community or county, people will perceive the risks of the facility as being unfair and less acceptable. For example, they are more likely to feel it is fair to be responsible for their own waste disposal, but unfair to accept wastes from another community.
- *Risk information that comes from trustworthy sources is more believable than information from untrustworthy sources.* If the public perceives a communicator as untrustworthy, then the information will be dismissed as biased, misleading, or otherwise unbelievable. Officials and individuals with vested interests in the outcome of the process will be seen as less credible, though some of the animosity can be diffused by admitting the biases up front.
- *Risks that are "dreaded" are less acceptable than those that carry less dread.* For example, groundwater contamination will be feared by the community more than risks from driving without seat belts, even when the former poses a lower risk to individuals. Because groundwater contamination is associated with cancer, which is dreaded more than a traffic accident, the perceived risks will be more serious.
- *Risks that are undetectable create more fear than detectable risks.* As an experienced war correspondent said at Three Mile Island, "at least in a war you know you haven't been hit yet." Similarly, risks with effects that take years to detect will be more likely to be feared.
- *Physical distance from a site influences the acceptability of risk.* Recent research found that people living near hazardous waste landfills were willing to pay between $200 and $500 per mile to move the landfill away from their neighborhood.
- *Rumor, misinformation, dispute and the sheer volume of information all may interact to give an incorrect perception of risk.* This "social amplification" is made worse by incomplete or inaccurate information, poor timing, and other social and political dynamics in the community.

USEPA, *Sites for Our Solid Waste: A Guidebook for Effective Public Involvement,* 1990

- Present technical information in language for a nontechnical audience.
- Discuss uncertainties and assumptions openly.

Although following these suggestions can help protect the credibility of technical information, it will not remove all challenges. If you are talking only to a leadership group, do not leave out any key interests. They will come back to haunt you later.

Addressing Negative Impacts, Both Perceived and Real

Planning for controversy and mitigation is crucial.

Some public policy positions in communities, no matter how sensitive to the concerns for residents, are bound to make some people feel they will be negatively impacted. Their concerns may be real or perceived. Few projects today are undertaken without some level of public controversy. If a solid waste facility is to be successfully sited today, it is necessary to find an immediate and direct means of resolving controversial issues. Planning for mitigation is a practical component of any solid waste project. Here are a few principles to follow in thinking about mitigation:

- The affected people want equivalent benefits—the people who experience impacts expect the attention of local government and may demand an equivalent share of the benefits of the project to offset the impact.
- The present level of risk is assumed to be zero. Any change in risk will be perceived as a potentially negative impact because people assume the present situation is without risk, or at least that risk has already been taken into account.
- Many mitigation issues are about procedure. When people are not sure of the impact of a project, they are very concerned with procedural protection and the credibility of decision makers.

Common concerns requiring mitigation include

- *process issues*
- *health risks*
- *environmental impacts*
- *community impacts.*

Common concerns about solid waste facilities that may require some form of mitigation include process issues, health risks, environmental issues, and local impacts, both perceived and real. Process issues include immediate access to facility management; representation on the facility's governing board; funds for independent review of technical studies; funds for a monitoring program. Environmental issues include air pollution, odor/litter, ground water, noise, dust, visual impact, wetlands protection, and waste flow reduction. Local impacts include negative neighborhood image/property values, traffic safety/congestion, and access/safety. There is often debate concerning whether local impacts, such as the effect of a landfill on property value, are real or only perceived. The economic impact on the project of funding additional technical studies or monitoring should be considered and discussed.

Developing an effective program to address impacts on the community requires careful planning. By carefully planning to address concerns, public controversy can be reduced significantly, which in turn increases the chances of successful siting. The basic steps in planning for impacts are

1. Identify the decision making-process for mitigation issues.
2. Identify the mitigation issues likely to arise.
3. Identify concerned segments of the public for each issue.
4. Identify forums for resolving mitigation issues with affected people.
5. Integrate required mitigation activities into the public involvement plan.

Evaluating the Effectiveness of the Siting Strategy

Project leaders make important decisions throughout the siting process based upon their judgment of the effectiveness of specific siting activities. Although there is no substitute for good judgment, evaluation can be a useful management tool to provide timely, cost-effective information that will improve the effectiveness of major siting activities.

Evaluating the process helps identify and address problems.

Evaluation is not an easy task. Many of the effects of the siting strategy will be difficult to measure; the strategy may succeed for one objective while failing on another. Evaluation may not be able to provide all of the answers, but it can provide important feedback.

Evaluation strategies can take different forms, depending on the type of information collected, the scope of the issues addressed, and the measurement techniques used. It is important to identify points in the siting process where evaluation can be most cost effective. People often form opinions at the beginning of the siting process, so it makes sense to pay careful attention to early siting activities.

Evaluations have different objectives, and several different evaluation designs are available. Despite differing evaluations, however, the six-step process outlined below will help develop a solid foundation for improving most siting strategies.

1. Set goals and objectives.
2. Determine information needs for the evaluation.
3. Collect the information.
4. Analyze the data.
5. Draw conclusions.
6. Review and adjust goals and objectives.

THE PERMITTING PROCESS

Permitting holds facilities accountable for protecting human health and the environmment.

The last step in the facility siting process should be a decision to seek the necessary permits to construct and operate the facility. At this stage, the community must seek the approval of regulatory authorities, including one or more federal, state, and local agencies required by law to insure that proposed projects meet minimum technical and legal criteria. The number of permits needed for a solid waste management project is determined by local laws and the type of waste management facility being planned.

Federal and state agency reviews usually focus on direct facility impacts such as emissions to air and water, although many states also require an environmental impact statement or assessment considering all potential project impacts. Indirect impacts, such as the project's effect on land use planning or property values, are normally considered at the local level. In some states, a local decision or ordinance denying a permit for a solid waste management facility can be overridden by the state.

The Structure and Goals of the Permitting Process

Permitting also ensures compliance with local public policy.

Permitting ensures that a proposed solid waste management project will not unduly affect the health and environment of the community and that it will be consistent with local public policy. To meet this goal, regulatory agencies must review detailed technical analyses developed and submitted by the project sponsor. Agency reviews compare the details of a proposed project with minimum criteria set forth as rules in an administrative code or local ordinance.

In addition to internal agency review, the permitting process normally allows for public input through hearings and submittal and receipt of written comments. The type and extent of public hearing rights are usually determined by the law governing the review process. Options range from a limited right to comment about a proposed activity to the right to request a trial-type proceeding at which evidence is presented and recorded and witnesses testify under oath and are cross-examined by attorneys.

After internal review with the benefit of public input, the reviewing agency must develop a written decision awarding a permit or disallowing the project. Reasons for the decision must be stated. Often, the issuing agency may grant a permit contingent upon compliance with a set of stated operating directives attached as permit conditions.

The entire permit proceeding is normally subject to review by a court. Completing a credible technical record from the inception of the project is crucial.

The entire permit proceeding is normally subject to review for correctness by a court. Opponents will usually use court review procedures to attempt to stop the project. To have the best chance of defeating legal challenges, it is important that a complete and credible technical record be developed from the inception of the project for presentation before the reviewing agency and that all procedural requirements and schedules be followed to the letter. Even successful permitting efforts can take many years and a significant commitment of project resources to complete.

Solid Waste Management Activities Requiring Permits

It is essential to accurately determine which permits are needed—a permitting oversight can stop a project dead in its tracks.

When planning a solid waste management project, it is essential to accurately determine which permits will be needed for the project. This point cannot be overemphasized. An oversight concerning a permit can stop a project dead in its tracks. A schedule for applying for and obtaining permits must be developed and closely followed to guarantee the best chance of success.

To determine permit needs, consult federal and state regulatory agencies and local planning agencies early in the siting process. Contact other communities that have developed similar programs to seek advice. Employing legal counsel with special expertise in solid waste facility siting and permitting can also help avoid delays or problems.

Source Reduction Programs

Efforts at source reduction may require new permits or permit revisions.

Efforts at source reduction may require new permits or permit revisions for equipment installed to reduce or capture emissions. If waste formerly emitted is now collected and stored, a waste storage permit may be needed. Make sure that the program meets regulations for employee and community right-to-know and emergency planning.

Recycling

Constructing a materials recovery facility (MRF) will normally require zoning approvals. To avoid problems, the facility should be characterized as a processing center, not a salvage yard or junk yard. A building permit and compliance with local building codes are required. For special circumstances, such as staffing by developmentally challenged workers, additional permits may apply.

Trucks transporting recyclable materials may need transport permits. If materials are to be transported across state lines, the Interstate Commerce Commission (ICC) should be contacted to determine if permits are needed. Some states may require permits for operating a recycling center or for certain facility operations involving emissions to the air or water or requiring solid waste storage. (Also see Chapter 6, "Recycling.")

Composting

Some states require compost operations to be permitted, especially municipal solid waste composting and large yard trimmings composting projects. Local zoning restrictions may also apply. Permits may also be needed for land application of yard trimmings or finished compost. (Also see Chapter 7, "Composting.")

Waste-to-Energy

WTE plants usually require a variety of permits and zoning and building approvals.

Like a large materials recovery facility, a waste-to-energy plant is a major construction project, usually requiring a variety of zoning and building approvals. Air emissions, solid waste storage, and water pollution discharge permits may be needed depending upon facility type and design. Permits for hauling ash may also be required. (Also see Chapter 8, "Combustion.")

Landfilling

States now require that landfills be permitted. A zoning variance or rezoning may also be necessary. Some local governments also have permitting requirements for landfills. (Also see Chapter 9, "Land Disposal.")

Collection and Transport

Solid waste haulers usually need a permit from either the state or local government, or from both.

REFERENCES

National Research Council. 1989. *Improving Risk Communication.* Washington, D.C.: National Academy Press.

USEPA. 1990. *Sites for Our Solid Waste: A Guidebook for Effective Public Involvement*. March.

USEPA. 1988. *Seven Cardinal Rules of Risk Communication.* April.

3

DEVELOPING A WASTE MANAGEMENT PROGRAM: FACTORS TO CONSIDER

No matter which waste management approach, or combination of approaches, a community decides to adopt, a variety of data must be collected and analyzed before the program can be implemented. The community's goals and the scope of the program must be set. The community must also understand its current and future waste generation profile in order to plan and finance an efficient and economical program.

Reliable information will allow the community to accurately budget for program needs, make it possible to design appropriately sized program facilities, and allow the community to better assess the program's success after it is implemented.

This chapter discusses techniques for applying all of the accepted options for preventing the generation of municipal waste or properly managing the materials that are generated.

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3 ❖ HIGHLIGHTS

Determining goals is the first step—source reduction should always be included.
(p. 3-4)

Communities should begin planning for new or continuing source reduction and waste management programs by first discussing the goals it is trying to achieve. A key goal should be source reduction which will eliminate the need to manage community waste. There are also many other valid goals; these include complying with state and federal law, protecting the environment, providing local business and job opportunities, and saving resources. By defining goals, the community can better determine the type of program it wants.

Characterizing the community's waste is a crucial step.
(p. 3-4 — 3-5)

Developing a successful waste management program requires accurate up-to-date information about the community's waste profile—what types of waste are generated, in what quantities, and how much of it can realistically be prevented through source reduction and collected for recycling.

The type of waste management program being considered will help determine the degree of detail needed in the waste characterization study. Source reduction and landfill projects require only gross waste volume from estimates. Recycling and waste-to-energy projects require accurate predictions of waste quantities and composition.

Several methods for characterizing waste are available.
(p. 3-5 — 3-9)

Modelling Techniques: Modelling techniques use generic waste generation rates and other information. They are inexpensive but provide only a general idea of waste volumes and types. Three aspects of modelling techniques are described in this chapter: generic weight generation data, generation rates for recyclables, and landfill volume estimates.

Physical Separation Techniques: Physical techniques are more accurate than modelling techniques, but are also more expensive and time-consuming. Such techniques sample the community's waste stream to develop a waste profile. Three sampling techniques are discussed in this chapter: quartering, block, and grid.

Direct Measurement Techniques: If done correctly, pilot studies can provide accurate volume estimates. Some communities are also weighing and characterizing the actual waste stream as it is collected. Bar code monitoring is another technique that provides highly accurate estimates of recyclable materials; such systems, however, are costly.

Estimating the amount of waste generation that can be prevented through source reduction or recycling is essential.
(p. 3-9 — 3-10)

It is unrealistic to assume that a community can completely prevent waste generation or recycle all the waste in its program. Even when waste characterization studies yield highly accurate information, some further estimate must be made of the actual percentage of material that the community can expect to collect. A variety of factors must be considered:

- Does your community have public or private collection?
- Does your community have businesses or industries that use private collection?
- Are there large numbers of residents who recycle on their own? Are there bottle deposit laws?
- Are there local ordinances (allowing residential burning, etc.) that may impact volumes?

The U.S. Supreme Court struck down a local flow control ordinance in May 1994.
(p. 3-10)

In May 1994, the U.S. Supreme Court struck down a local flow control ordinance that required all solid wastes to be processed at a designated transfer station before being sent out of the municipality. In *C&A Carbone, Inc. v. Town of Clarkstown*, the Court found that the flow control ordinance violated the Commerce Clause of the Constitution because it deprived competitors, including out-of-state businesses, of access to the local waste processing market.

The flow control debate has caused many cities to use alternative financing methods.
(p. 3-10)

As a result of the continuing debate over the use of flow control, many cities are using alternative methods to finance programs. Methods include the following:

- municipal collection in which the city can set tipping fees at publicly owned or financed facilities at noncompetitive prices
- taxes (property, income, sale of goods or services)
- user fees or surcharges.

Estimating future waste generation is also crucial.
(p. 3-11)

Some waste management alternatives, such as waste-to-energy, rely on a steady supply of material over long periods of time, up to 20 years or more. The two most important trends to investigate are population and public policy changes. Legislatively mandated recycling and composting programs can reduce waste volumes significantly. Caution is essential in sizing facilities—an oversized facility can bring economic disaster. Waste composition changes are also important.

Consider the following factors when organizing a waste management program.
(p. 3-14 — 3-16)

Establishing a waste management program is a lengthy and complex process; the following considerations are crucial to long-term success.

- formulating and following a well-devised and comprehensive plan
- basing decisions on sound economic analysis
- keeping public participation rates high over a number of years requires an ongoing education and publicity plan
- acquiring and maintaining political support should be an ongoing effort
- many waste management projects take from five to ten years to implement. The ultimate key to success is the will to persevere—the thousands of successful programs underway nationwide attest to this.

3 DEVELOPING A WASTE MANAGEMENT PROGRAM: FACTORS TO CONSIDER

DEVELOPING THE NECESSARY INFORMATION BASE

Identify Goals and Scope of the Program

Defining goals early facilitates later decision making.

Every community should begin planning for new or continuing source reduction and waste management programs by first discussing the goals it is trying to achieve. A key goal should be source reduction which will eliminate the need to manage community waste. There are also many other valid goals; these include complying with state and federal law, protecting the environment, providing local business and job opportunities, and saving resources. By defining goals, the community can better determine the type of program it wants.

For example, if a community is interested only in the economic benefits of a recycling program, it may choose to recycle only the most cost-effective items, such as aluminum. Items that are more costly to collect or have low market prices such as plastic may be excluded from the program. On the other hand, if a community's goal is to preserve landfill space and conserve resources, the community may decide to strongly support source reduction and to collect a larger variety of items, even if collecting some materials results in higher unit costs. Defining community goals up front will make later decisions about program scope and degree of economic commitment easier.

Once goals are determined, the scope of the intended program must be defined. Will the program be community wide? Will a regional approach cover all sectors, including residential, commercial, and industrial sectors? By answering these questions, the proposed program will be put into focus. Defining program scope will help develop program organization and ensure waste characterization analyses are useful and cost effective.

Characterize Quantity and Composition of Material

Successful program planning depends on reliable information about quantities, types, and how much material can be captured.

The cornerstone of successful planning for a waste management program is reliable information about the quantity and type of material being generated and how much of that material collection program managers can expect to prevent or capture. Without a good idea of the quantities that can be expected, decisions about equipment and space needs, facilities, markets, and personnel cannot be reliably made. This also identifies large weight and volume waste items to target for source reduction and recycling programs and gives baseline data for assessing whether goals were achieved.

Depending on the size of the program and the resources available to the community, there are a variety of waste characterization techniques that can be used. First, there are modelling techniques that apply generic waste generation rates and other community features to predict the waste quantities and types. These techniques are inexpensive and can provide a general idea of the quantities and types of waste expected for a program just starting up.

To plan successfully, know your community's waste stream:

- *types of waste*
- *amounts of each*
- *"capturable" quantities.*

More accurate in describing the waste stream, but also more expensive and time consuming to implement, are the physical separation techniques. These techniques sample the community waste stream itself, using statistically significant sampling techniques to determine a community waste generation profile. Depending on community goals, both have a place in developing an effective waste management program. Some form of waste characterization estimate is crucial to program success, because later decisions will be based on this information.

The waste management option being considered will help determine the degree of detail needed from the waste characterization study. For a landfill project, only gross waste volume estimates are needed to help determine space needs. This is also true of estimating yard waste volumes for a windrow composting program. For these types of management strategies, generic and historically based waste generation rates may provide acceptable accuracy.

For other alternatives accurate predictions of waste volumes and composition are crucial to long-term program success. Accurate characterization will allow certain waste to be targeted for source reduction efforts. Many facets of a recycling program, including the size of a material recovery facility, the volume of recyclable material to be sold, and equipment and personnel requirements for collection are dependent on accurate characterization of the waste stream. For a waste-to-energy project, both sizing the facility and calculating the quantity of energy that the facility will generate are based on characterizing waste volume and type. In the long term, the quantity of waste available for the facility will be affected by other options, including source reduction, recycling and composting. Inaccuracies in waste characterization studies for these alternatives can severely and negatively impact the economic viability of the program.

When determining which composition technique to use, the costs of gathering the necessary data should be compared with the limits of precision needed to make reliable estimates. Future community trends, such as population growth, must also be considered in developing a waste characterization profile.

MODELLING TECHNIQUES

Generic Weight Generation Data

For residential waste, the multiplier is usually pounds of waste generated per person per day. This can be estimated from previous records if the population and weight of refuse are known. If not, a weighing program may be necessary to determine if refuse weights can be obtained for a known population. Typical figures for the United States are 2.5 to 3.5 pounds / person / day for residential waste. More recent USEPA projections suggest that Americans generate 4 pounds / person / day with the generation rate expected to increase (see Table 3-1). Once the multiplier is developed, population projections can be used to project tonnages. However, projections of waste volume using average rates should not be used for planning specific facilities.

Recent USEPA projections suggest that Americans generate 4 pounds/person/day (see Table 3-1).

The trend in the per capita generation rate is not clear: Table 3-1 predicts that the rate is increasing at about 5 percent per year, while other projections indicate no increase. Many communities are making significant efforts at waste reduction. Unless there is information to the contrary, it is best to assume no change in the generation rate and to develop future projections based on population projections alone.

Table 3-1

Projected Per Capita Generation of Municipal Solid Waste by Material, 1980-2000*
(in pounds per person per day—generation before materials or energy recovery)

Material	1980	1990	1993	2000
Paper and paperboard	1.32	1.60	1.65	1.77
Glass	0.36	0.29	0.29	0.28
Metals	0.35	0.36	0.36	0.38
Plastics	0.19	0.39	0.43	0.47
Rubber and leather	0.10	0.13	0.13	0.15
Textiles	0.06	0.13	0.11	0.10
Wood	0.16	0.27	0.29	0.32
Other	0.07	0.07	0.07	0.07
Total nonfood products	2.62	3.23	3.34	3.54
Food scraps	0.32	0.29	0.29	0.28
Yard trimmings	0.66	0.77	0.70	0.44
Miscellaneous inorganic wastes	0.05	0.06	0.06	0.07
Total MSW generated	3.65	4.35	4.39	4.32

**Details may not add to totals due to rounding.*

Source: USEPA. *Characterization of Municipal Solid Waste in the United States: 1994 Update*

Generation Rates For Specific Waste Types

Generation rates used must correspond to the community.

For specific waste types a general estimate of the tonnage available can be obtained by multiplying the local community population by a generic generation rate (see Table 3-2). Care must be taken to determine that the generic rate is applicable to the community. If available, use composition data from a study of a community located in the same region as the target community. Even when using generic data, unique local features, such as a community being located in a tourist area with many restaurants and bars and a higher seasonal population, should be taken into account. Seasonal variations in waste generation and the contribution of commercial and institutional facilities should also be considered.

Table 3-2

Recyclable Household Waste

Recyclable Household Wastes (pounds per person per year)

	Urban	Rural
Newspaper	75–125	50
Metal	60–75	50–75
Appliances	20–25	20–25
Clear glass	40–60	40
Colored glass	25–40	25
Plastic containers	6	6
Motor oil	1/2 Gallon	1/2 Gallon
Food scraps & yard trimmings	100–250	100–250
Leaves	Unknown	Unknown

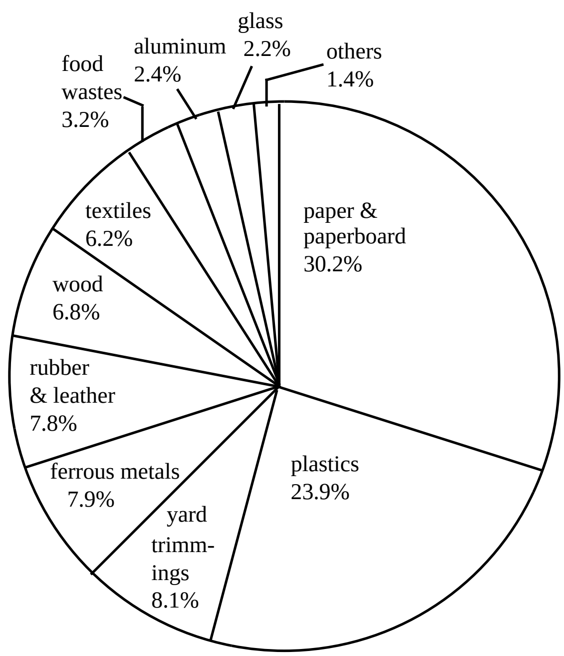
Reindl, J. "Source Separation Recycling" (unpublished, 1983)

Getting accurate estimates requires knowledge of local and regional conditions.

Where the community is served by a landfill with a scale, generic waste composition data can be applied to determine the amounts of recyclables available (see Figure 3-1). This estimate too must be carefully scrutinized to take into account local conditions. For small- or medium-sized communities, where a percent or two of difference either way is not important, using actual weight data and multiplying by percentage data may provide a good initial estimate. With this method as well, special regional characteristics should be noted and taken into account to help fit the estimate to local conditions. For this method, it is important to know the types of waste accepted at the landfill. If the landfill accepts special large-volume wastes, such as power plant ash or foundry sand, the accuracy of weight-based estimates may be questionable, since the waste profile of the landfill will not reflect the generic averages.

Figure 3-1

Landfill Volume of Materials in MSW, 1993 (in percent of total)



Source: USEPA. *Characterization of Municipal Solid Waste in the United States: 1994 Update*

Landfill Volume Estimates

For landfills lacking a scale, only rough estimates can be obtained by counting trucks arriving at the landfill and estimating the volume in each truck.

For a community with a landfill that lacks a scale, a very rough estimate of the total volume of waste generated can be obtained by counting the number of trucks arriving at the landfill and multiplying the number by an estimate of the volume in each truck. This figure can then be multiplied by composition data to further estimate the expected quantity of various waste types, if necessary. The uncertainty inherent in this technique is great, because of the heterogeneous nature of municipal solid waste. Also, to take into account the variability of the waste stream throughout the year, the volume analysis would have to be performed a number of times during the year to improve its reliability. For specific projects, this approach would not provide an acceptable degree of accuracy.

PHYSICAL TECHNIQUES

Sampling Techniques

Sampling techniques use statistical methods to predict total waste stream quantity and composition by analyzing small volumes.

Sampling techniques use statistical methods to predict total waste stream quantity and composition by analyzing small volumes. Each technique attempts to obtain a representative, random sample of the waste stream. For full-scale characterization, the physical techniques should be performed at least four times over the course of a year, to take into account seasonal variation. Likewise, for each sampling point, care should be taken to ensure that results are not skewed by seasonal events. For example, the week after Christmas, the percentage of paper from wrapping is much higher than normal.

- **Quartering technique:** This technique can be used to sample a truck load or a group of truck loads of waste. When sampling a community, it is useful to choose a group of refuse trucks from various neighborhoods. By sampling a representative grouping of trucks, the community as a whole can be characterized better.

  For each truck, unload an agreed upon quantity of waste in a cleared area at the disposal site or transfer station. Mix the various collections of waste thoroughly with a front end loader. Rake the sample into quarters and mix again thoroughly. Continue quartering the sample and mixing until a representative sample weighing greater than 200 pounds is generated. The sample should then be weighed and separated into its components. Each recyclable category should be weighed and compared with the total.

For accurate estimates, sample four times in a year, avoiding "seasonal events" like Christmas.

- **Block technique:** The block technique can be used instead of the quartering technique when mixing a group of samples might be difficult. Using this technique, the load samples of refuse are dumped in a clear area, but rather than mixing the loads, the sampling team chooses what it deems to be a representative sample from the loads. The representative sample is then separated and characterized. The accuracy of this technique is highly dependent on the ability of the sampling team to define a representative sample.
- **Grid technique:** In this technique, the floor of a transfer station or a cleared area of a landfill is divided into equal size squares, with each square assigned a number and letter code for identification. Waste is unloaded onto the grid and mixed with approximately equal quantities of waste placed in each square. Waste characteristics are then determined for a set number of grid squares and compared with the weight or volume of the entire load.

DIRECT MEASUREMENT TECHNIQUES

A pilot study can provide information about the type and volume of material generated in the community.

Conducting a pilot study can provide information concerning the type and volume of material generated in the community. Different collection methods can be tested to determine comparative participation and generation rates. Data collected from the pilot may provide an accurate estimate of the volume of material expected from a community-wide program if care is taken to design the program to represent the demographics of the community and to publicize the program in the target neighborhood.

Increasingly, communities are also developing methods of weighing and characterizing the actual waste stream collected from a community. A number of American communities with volume-based fee systems now use bar-

Several communities with volume-based fee systems use bar-code monitoring to determine the weight and type of materials collected from each generator.

code monitoring to determine the weight and type of materials collected from each generator in the community for billing purposes. The city of Seattle is experimenting with the bar-code system and hopes to initiate a weight-based charge system for its waste management program. Other programs, including St. Louis Park, Minnesota, and Fitchburg, Wisconsin, are using the bar-code system to determine the types of materials collected and participation rates. In recycling programs bar-code systems yield highly accurate waste characterization information, but have been criticized for being costly, slow to implement, and unnecessary (see Table 3-3). If more large communities move to weight-based charging systems, bar-code monitoring may become a more accepted method for determining waste characterization.

Table 3-3

Advantages and Disadvantages of Bar-Code Monitoring

Advantages	Disadvantages
• Provides more reliable participation figures than route auditing with hand counters. • Can be cost efficient, over the long term. • Helps increase participation when used with reward system; can also be used with penalty system. • Enables targeting of nonparticipants for education and promotion programs. • Gauges effectiveness of advertising. • Allows crews to enter additional information, such as types of materials. • Allows managers to keep better track of crews. • Makes efficient routing easier.	• Capital costs can be significant. • Implementation is often difficult. • Can increase collection time. • Possible resistance from crews because of increased hassle, reduced freedom. • Possible resistance from customers because of "Big Brother is watching me" perception.

Source: T. Watson

ESTIMATING THE PERCENTAGE OF MATERIAL THAT MUST BE MANAGED

It would be unrealistic to assume a community can capture or prevent all the waste in its program. This is especially true for recycling. Even when waste characterization studies yield highly accurate information, some further estimate must be made of the actual percentage of material that the community can expect to collect. A variety of factors must be considered.

Legal Control Over Waste Materials

Private collection and other factors affect amounts of recyclables.

For communities that have public collection, control of waste materials may not be a problem. However, many communities are served by private haulers who usually control the waste after it is collected. Even in communities with public pickup, businesses and institutions may be served by private haulers. Some of these businesses, such as restaurants and food stores, may produce large volumes of high-quality recyclables or combustibles that the community may want to capture for its program (see Table 3-4). Unless legal control can be obtained over a certain waste type, it should not be included in the community's plans.

The U.S. Supreme Court struck down a local flow control ordinance, which required all waste to be sent to a designated facility.

Many cities are using alternative methods of financing as a result of the flow control controversy.

Some private haulers are happy to use a local community facility because using a local facility reduces transport costs or means the hauler does not have to find acceptable markets for the recoverable materials. However, many hauling companies around the country are now offering waste processing services to customers and are constructing recycling centers and compost sites of their own. Or, a community considering a recycling or waste-to-energy program may already have a nonprofit or private recycling operation in its area. If the community attempts to take over the waste stream, the viability of the existing public and private programs may be jeopardized. Exploring cooperative arrangements with existing recycling programs is recommended.

On May 16, 1994, the U.S. Supreme Court struck down a local flow control ordinance that required all solid wastes to be processed at a designated transfer station before being sent out of the municipality. In *C&A Carbone, Inc. v. Town of Clarkstown*, the Court found that the flow control ordinance violated the Commerce Clause of the Constitution because it deprived competitors, including out-of-state businesses, of access to the local waste processing market.

As a result of the continuing debate over the use of flow control, a number of cities have opted for alternative methods to finance their solid waste systems. Methods include municipal collection in which the city can set tipping fees at publicly owned or financed facilities at a noncompetitive price and thereby subsidize other municipal solid waste programs and services, taxes (property, income, sale of goods or services), and user fees or surcharges.

In considering alternative financing mechanisms, local governments should carefully weigh options against the adequacy of revenue in terms of revenue-raising potential and consistency and in terms of reliability over time, equity, political feasibility, administrative ease, and impact on innovation.

Table 3-4

Recyclable Material in the Commercial Waste Stream (by type of business, in percent)

Waste component	Retail trade	Restaurant	Office	School	Gov't
Paper	41.5	36.6	64.2	47.8	53.8
Newspaper	2.9	2.5	3.6	3.3	6.7
Corrugated	22.0	15.6	11.5	11.6	8.4
High grade white	1.4	0.0	0.6	6.3	7.2
Mixed recyclable	10.3	4.4	29.0	21.6	25.0
Nonrecyclable	4.9	14.1	9.5	5.0	6.5
Plastic	12.0	13.7	4.3	5.1	3.5
PET (1)	0.1	0.0	0.1	0.1	0.1
HDPE (2)	0.0	0.1	0.0	0.0	0.0
Other	11.9	3.6	4.2	5.0	3.4
Glass	2.5	5.9	3.9	3.2	2.7
Container	2.3	5.9	2.9	1.0	2.4
Nonrecyclable glass	0.2	0.1	1.0	2.2	0.3
Metal	20.5	4.9	2.9	5.8	9.8
Aluminum cans	0.2	0.5	0.5	0.8	0.5
Tin/steel cans	0.2	3.8	0.2	0.2	0.4
Other ferrous	19.5	0.4	2.2	3.7	8.6
Other non-ferrous	0.6	0.2	0.0	1.1	0.3
Organics	18.8	36.6	10.8	35.0	23.2
Food waste	8.1	36.0	3.0	14.0	32.0
Yard debris and wood	10.7	0.6	7.8	21.0	20.0
Other	4.7	2.3	13.9	3.1	7.0
Totals	100.0	100.0	100.0	100.0	100.0

Source: Washington State Department of Ecology. *Best Management Practices for Solid Waste: Recycling and Waste Stream Survey*, 1987

Personal Waste Management

For some recyclables, especially aluminum cans, personal recycling may significantly reduce the volume available to the community program. A state beverage container deposit law will also reduce available volumes of aluminum, glass, and perhaps plastic. For other recyclables, such as newsprint, personal recycling may not be a factor.

As costs rise, many rural residents may manage wastes using burn barrels. Some residents may choose to not pick up grass clippings or other yard waste. Local ordinances may influence these practices.

To determine volumes, consider carefully the impact of personal source reduction and recycling.

In determining program volumes, therefore, the impact of personal source reduction and recycling on the quantity of materials economically available to the community should be considered. Because price paid to individuals for recyclables can impact personal recycling to a significant degree, some prediction of market conditions for recyclables should be made in making this determination.

ESTIMATING FUTURE WASTE GENERATION

As alternatives for managing or preventing waste are investigated, it is important to make an attempt to accurately predict future trends in community waste generation. While this may be difficult, it is crucial to long-term program viability. Some alternatives, such as constructing a waste-to-energy facility, are financed based on a 20-year facility life. A drastic drop in waste delivered to a facility of this type could have severe economic consequences for the community that owns it.

The two most important trends that should be investigated are population and public policy changes. Population trends are usually monitored carefully. Some realistic prediction of the rate at which the community population is changing should be made.

Accurate estimates of population trends and future public policy decisions are crucial.

Public policy shifts can quickly change the quantity and type of waste materials available to support a given option. For example, constructing a landfill or waste-to-energy facility without considering the possible impact of a trend toward legislatively mandated source reduction, recycling and composting programs could be risky. If there is great uncertainty, conservatism in sizing the facility is warranted. Facilities can usually be expanded. Oversizing a waste-to-energy facility, on the other hand, can be an economic disaster.

Changes in the composition of the waste stream should also be noted. Estimates developed by Franklin and Associates for the USEPA predict growth in plastics packaging and a decline in glass packaging between the years 1995 and 2010 (see Table 3-5). While generic estimates are difficult to apply locally, these predictions should be considered when planning the program.

Statewide waste composition projections can also assist future planning. Table 3-6 sets forth recycling projections for the state of New Jersey through the year 1995. New Jersey communities can use this information to set goals and perform planning to keep pace with statewide waste management efforts.

Gauging Program Participation and Effectiveness

Evaluating effectiveness is crucial, especially in states with source reduction and recycling mandates.

Determining waste prevention rates participation rates, diversion percentages, waste energy values, and other program parameters over the long term is necessary to properly evaluate program progress. Some states now require communities to meet specified percentages for source reduction and recycling. Reliably calculating these parameters is difficult, however.

Defining which materials to count in the calculation can present a major problem. Some states include junked autos and yard trimmings in waste diverted for recycling. Others do not. The first step in developing a procedure

Table 3-5

Projections of Materials Generated* in the Municipal Waste Stream, 1993 and 2000
(In thousands of tons and percent of total generation)

	Thousands of Tons		% of Total Generation	
Materials	1993	2000	1993	2000
Paper and Paperboard	77,840	89,340	37.6%	41.0%
Glass	13,670	14,020	6.6%	6.4%
Metals				
Ferrous	12,930	14,220	6.2%	6.5%
Aluminum	2,970	3,425	1.4%	1.6%
Other Nonferrous	1,240	1,395	0.6%	0.6%
Total Metals	*17,140*	*19,040*	*8.3%*	*8.7%*
Plastics	19,300	22,490	9.3%	10.3%
Rubber and Leather	6,220	7,610	3.0%	3.5%
Textiles	6,130	6,200	3.0%	2.8%
Wood	13,690	16,010	6.6%	7.4%
Other	3,300	3,540	1.6%	1.6%
Total Materials in Products	*157,290*	*178,250*	*76.0%*	*81.9%*
Other Wastes				
Food Wastes	13,800	14,000	6.7%	6.4%
Yard Trimmings	32,800	22,200**	15.9%	10.2%
Miscellaneous Inorganic Wastes	3,050	3,300	1.5%	1.5%
Total Other Wastes	49,650	39,500	24.0%	18.1%
Total MSW Generated	*206,940*	*217,750*	*100.0%*	*100.0%*

*Generation before materials recovery or combustion
**This scenario assumes a 32.3% reduction of yard trimmings.
Details may not add to totals due to rounding.

Source: USEPA, *Characterization of Municipal Solid Waste in the United States: 1994 Update*

Table 3-6 New Jersey Statewide Recycling Projections: Five-Year Rate (in thousands of tons/year)

			Current Status			Projected '95 Goal		1995 Residue	
Materials	Total % Waste Stream[1]	Total 1990 Generation[2]	Rate (%)[3]	Tonnage[4]	Total 1995 Generation[5]	Rate (%)[6]	Tonnage[7]	Tonnage[8]	% Total[9]
Yard waste	10%	1,420	49%	699	1,458	90%	1,312	146	3%
Food waste	5%	681	9%	63	700	10%	70	630	12%
Newspapers	5%	717	66%	472	737	85%	626	110	2%
Corrugated	6%	841	50%	417	864	85%	734	130	2%
Office paper	2%	359	59%	210	368	85%	313	55	1%
Other paper	10%	1,484	0%	0	1,525	20%	305	1,220	23%
Plastic containers	1%	169	1%	2	174	60%	104	69	1%
Other plastic packaging	1%	177	0%	0	182	25%	45	136	3%
Other plastic scrap	3%	457	0%	2	469	10%	47	422	8%
Glass containers[10]	3%	366	53%	193	376	90%	338	38	1%
Other glass	1%	79	0%	0	81	0%	0	81	2%
Aluminum cans[11]	0%	43	44%	19	44	90%	40	4	0%
Foils and closures	0%	22	0%	0	22	0%	0	22	0%
Other aluminum scrap[12]	0%	60	55%	33	62	80%	49	12	0%
Vehicular batteries	0%	40	93%	37	41	95%	39	2	0%
Other non-ferrous scrap	0%	55	60%	33	56	95%	54	3	0%
Tin and bi-metal cans	1%	122	18%	22	125	85%	106	19	0%
White goods and sheet iron	2%	340	62%	211	349	90%	314	35	1%
Junked autos[13]	4%	625	99%	619	642	99%	636	6	0%
Heavy iron	7%	1,037	100%	1033	1,071	99%	1,061	11	0%
Wood waste	9%	1,232	11%	133	1,265	75%	949	316	6%
Asphalt, concrete and masonry	16%	2,311	82%	1,884	2,374	90%	2,136	237	4%
Tires	1%	141	13%	18	145	30%	43	101	2%
Other municipal and vegetative	4%	631	4%	27	648	10%	65	583	11%
Other bulky and constructive demolition	7%	946	0%	0	972	10%	97	875	17%
Totals	100%	14,355	43%	6,128	14,750	64%	9,485	5,265	100%

Footnotes

(1) Calculated by dividing the 1991 generation tonnage for each material by the total tonnage figure of 14,355.

(2) Tonnages derived following the estimation of the percent of the waste stream made up by each material. These percentage estimates were taken from national figures prepared by Franklin Associates Ltd. from the report entitled "Export Markets for Post Consumer Secondary Materials," from values of the 18 waste characterization studies done by the New Jersey counties or from the values of four bulky waste analysis studies performed by New Jersey counties. These percentages were then multiplied by the municipal and/or bulky waste stream totals from the Baseline 1991 Generation Table. In some cases, tonnage estimates were obtained directly from industry sources.

(3) Current recycling rates, which represent documented activity for calendar year 1989, were calculated by dividing the reported tonnage figure by the total 1991 generation estimates of each material.

(4) Most current tonnages were actual documented figures from the 1989 Recycling Tonnage Grants Program. In a few cases, particularly with glass containers, the metals categories, and asphalt, concrete and masonry, numbers were received directly from industry sources documenting activity in 1989.

(5) 1995 generation estimates based exclusively on projected overall population of 4.7% by county from the New Jersey Department of Labor economic demographic model. No per capita change or source reduction assumed.

(6) Projected 1995 recycling percentages represent the goals or targets established by material from the Emergency Solid Waste Assessment Task Force and presented within their August 6, 1990, Final Report.

(7) Projected 1995 tonnage calculated by multiplying the estimated recycling percentage of the total 1995 generation figure by material.

(8) 1995 residue calculated by subtracting the projected 1995 recycling tonnage from the 1995 total generation figure by material.

(9) This column represents an estimate of the percentage of 1995 generation residue made up by each material. The calculation was derived by dividing the 1995 residue tonnage of each material by the total residue tonnage of 5,265.

(10) Glass containers figures derived primarily from the Glass Packaging Institute container generation estimates for 1989.

(11) Based on ALCOA generation estimate of 11 lbs. per capita per year.

(12) Based on NJ Auto and Metal Recycling Association generation estimate.

(13) Junked autos recycling rates are exclusive of shredder fluff.

Source: New Jersey Department of Environmental Protection for judging program progress is to develop program definitions and stick with them. Contact your state for guidance.

An overly broad definition of participation rates can result in cost inefficiency and lower-than-predicted volumes.

Participation rates should be carefully defined, because they can be misleading. For example, some recycling programs claim high participation rates, but some residents included in those rates contribute only one type of recyclable or participate infrequently. While high participation rate calculations are politically attractive, an overly broad definition of participation can result in cost inefficiency and lower-than-predicted volumes of material collected. A participation rate that counts regular participation in the entire collection program could provide a more accurate estimate for program assessment purposes.

Using defined parameters, a data collection system can be devised. For most communities, simply weighing waste loads at the landfill may not provide enough information. Simple data collection using log sheets or mechanical counters can be used if set-out rate, number of loads, and material weight are the only types of information wanted. Some communities use a computerized data collection system consisting of a hand-held computer and personal computer with spreadsheet software to collect more detailed program information. As stated earlier, pilots using bar coding and weighing waste from individual generators are in progress around the country.

The data collected can then be used to develop a profile consisting of participation rates, wastes types and volumes generated, quantities and percentages of compostables, recyclables and burnables actually captured, and other important information source reduction can be tracked. Cost efficiency of collection and processing and educational needs can also be assessed.

ORGANIZING A WASTE MANAGEMENT PROGRAM

The process of establishing a waste management program is lengthy and complex. As the process moves along and problems arise, it is easy to get bogged down in the everyday details of program implementation. Frequently, an immediate problem can take precedence and seemingly overshadow all other considerations. Although the need to break a complex problem into small, workable units is human nature, the “big picture” must always be kept in focus.

Successful organization focuses on the 5 "Ps":

- *Planning*
- *Price*
- *Publicity*
- *Politics*
- *Perseverence*

As a community moves toward program implementation, managers must constantly remind themselves to keep the overall program in perspective. By viewing the project as a whole, no individual element will be given too much or too little attention. Program momentum will be sustained at a slow, but steady, pace. Issues that can delay or derail a program will be recognized and dealt with. Public support will be fostered and confidence in the ability of the community to successfully implement a program will grow.

To keep a waste management program in its proper perspective, attention must be given to the five “Ps”; that is, planning, price, publicity, politics, and perseverance. By always remembering the five Ps, program developers will give their programs the greatest chance of succeeding. Conversely, if any one of the Ps is ignored or forgotten, the program has a great chance of failing. Each of these issues is discussed briefly below.

Planning

Although it may seem obvious that planning is needed to implement a successful program, in practice, the need to formulate and follow a well-devised and comprehensive plan is sometimes forgotten. A leaking landfill or other waste management problem may pressure a community to act quickly; hasty actions cause mistakes, which in turn result in delays and wasted resources. While all possible situations cannot be anticipated, many good models based on successful programs do exist, and program developers are encouraged to use them when possible to formulate their own programs.

For example, in waste-to-energy projects, a number of communities have run into trouble because financing expertise was not brought into the planning process early enough. After significant resources were committed to technical analysis, the capital markets were consulted only to reveal that the technical information compiled and recommendations made were inadequate to provide proper support to obtain capital financing. As a result, the technical analysis had to be redone, which added cost and delay to the project.

Planning is especially important because of the large number of actors involved with a waste management program.

Planning is especially important because of the potentially large number of actors in the waste management process. Political bodies, waste generators, waste haulers, regulatory agencies, construction contractors, plant operators, energy and material buyers, landfill site owners, and citizens must all be included for a program to be successful. Each group has the potential for delaying or derailing a project. By formulating and continually reviewing a project plan, program managers can minimize the chances that a major component of the program will be missed.

Price

Each management approach carries a price tag. Comparing costs and benefits before acting is essential to long-term success.

Decisions regarding the adoption of alternative strategies for managing waste must continually be based on sound economic analysis that considers the resources of the community and the anticipated environmental impacts and benefits. The community is usually willing to support higher cost waste management options as long as there is confidence that the program is well run, economically efficient, and environmentally sound. Each management approach carries a price tag. Comparing costs and benefits before action is essential to long-term success.

Publicity

Program support can erode quickly. Ongoing publicity efforts to maintain strong, positive public support are crucial.

Successfully implementing a waste management program can take a number of years and a commitment of community resources worth many millions of dollars. While the decision to pursue a certain option is often met with great fanfare, support for a program can erode quickly unless attention is given to keeping the program on the public agenda and maintaining strong and positive public support. A plan for informing the public about the program's progress should be developed and implemented as the program proceeds. Special effort should be made to generate public support before public bodies vote on program expenditures. The program must be seen by the public as something to be proud of, as an example of the progressiveness of the community and its commitment to a clean environment.

Politics

Political support is crucial to obtain financing and ensure the program gets the resources needed to construct facilities and operate them efficiently.

As with publicity, sustaining political support during the long and costly implementation process is vital to the program's ultimate success. When local government budgets are tight, a program may not survive the budget cutter's knife unless there is continuing, strong political support. Political support is often crucial to obtaining financing and ensuring that the program gets the resources needed to construct facilities and operate them efficiently. Political leaders should also be kept informed of the program's progress on a regular basis so that political support for the program grows as the decision-making body reaches the point of actually committing its public or private resources to implementing the long-term program. Newly elected political officials must also be educated concerning the community effort.

Perseverance

Finally, a community considering a waste management program must be prepared for the long term. Some projects can take five to ten years to implement. Such programs are complex, expensive, and often frustrating. A community choosing to implement a program must be willing to commit the necessary resources to see the program through. The ultimate key to success is the will to persevere until the program is in place; the thousands of successful programs underway nationwide attest to this.

REFERENCES

USEPA. 1990. *Characterization of Municipal Solid Waste in the United States: 1990 Update.*

USEPA. 1992. Characterization of Municipal Solid Waste in the United States: 1992 Update.

Washington State Department of Ecology. 1987. *Best Management Practices for Solid Waste: Recycling Waste Stream Survey*.

4

COLLECTION AND TRANSFER

Efficient, sanitary, and customer-responsive collection of solid wastes is at the heart of a well-run waste management system. Collection services are provided to residents in virtually all urban and suburban areas in the United States, as well as some rural areas, either by private haulers or by municipal governments.

The types of collection services have expanded in many communities in recent years to include the special collection or handling of recyclables and yard wastes. Even though disposal costs continue to grow rapidly across the United States, the costs of collecting wastes continue to outpace disposal as a percentage of overall service costs for most communities.

This chapter addresses issues to consider when planning a new collection system or when evaluating changes to an existing system.

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4 ❖ HIGHLIGHTS

The community should define its goals and constraints.
(p. 4-5 — 4-6)

Each community should clearly define the goals for its collection system, periodically review the system's performance in meeting those goals, and regularly review and adjust the system's goals to conform to the community's changing needs.
To define collection system goals, consider the following issues:

- the level/quality of service your community needs
- the roles to be played by the public and private sectors
- the community's long-term waste management and source reduction goals
- preferences for and constraints on available funding mechanisms
- existing labor/service contracts that may affect decision making.

Both public and private operation should be considered and evaluated.
(p. 4-6 — 4-7)

The municipality should determine appropriate roles for the public and private sectors. The collection system may be operated by (1) a municipal department, (2) a contracted private firm or firms, or (3) a combination of public and private haulers. Regardless of the management options chosen, a clear organizational structure and management plan should be developed.

Explore alternative funding methods to determine which is appropriate.
(p. 4-7 — 4-10)

Explore alternative mechanisms for funding collection services. The two most common funding methods are property taxes and special solid waste service fees. However, communities are turning more to user-based fees, which can stimulate waste reduction efforts and reduce tax burdens. Economic incentives can be used to reduce waste generation by charging according to the amount of waste set out. When selecting a funding method, considering waste reduction and management goals is important. Table 4-2 lists advantages/disadvantages of alternative funding mechanisms.

Waste preparation and collection procedures should be coordinated.
(p. 4-10 — 4-13)

Decisions about how residents prepare waste for pickup and which methods are used to collect it affect each other and must be coordinated to achieve an efficient, effective system. Decisions about the following must be made:

- *Solid waste set-out requirements:* guidelines and ordinances specify how residents should prepare solid waste and recyclables for collection should be developed.
- *Point and frequency of collection*: how often to collect waste and from what points (curbside, backyard, etc.) must be decided.

Collection equipment must be carefully chosen.
(p. 4-13 — 4-15)

Numerous types of collection vehicles and optional features are available. For specific equipment design information, contact equipment vendors and review existing equipment needs. Table 4-4 presents criteria for choosing the most appropriate equipment. Cost information and expected service life should be gathered and evaluated.

❖❖

Is a transfer facility appropriate for your community?

(p. 4-16)

To determine if a transfer system is appropriate for your community, compare the costs and savings associated with the construction and operation of a transfer facility.

Benefits:

- lower collection costs
- reduced fuel and maintenance costs for collection vehicles
- increased flexibility in selecting disposal facilities
- the option to separate and recover recyclables or compostables at the transfer site
- the opportunity to shred or bale wastes before disposal.

Possible drawbacks:

- difficulty with siting and permitting, particularly in urban areas
- construction and operation costs may make them undesirable for some communities (especially for communities *less than* 10 or 15 miles from the disposal site).

Consider these crucial factors when selecting a collection and transfer alternative.

(p. 4-28 — 4-30)

The following factors are usually important to public officials when evaluating collection and transfer alternatives:

- costs of required new equipment and ability of community to obtain financing for it
- costs to operate collection system and transfer facilities
- compatibility of total costs with budget available for solid waste services
- differences in levels of service provided by alternative systems
- ability of system to meet public's demands or expectations for service
- proposed methods for financing system costs and public acceptability of those methods
- the system's effects on efforts to meet the community's waste reduction and management goals
- compatibility of proposed roles for public and private sectors with political support for them
- public's interest or disinterest in changing present arrangements for collecting solid waste and recyclables.

Developing efficient routes and schedules decreases costs.

(p. 4-30 — 4-32)

Detailed route configurations and collection schedules should be developed for the selected collection system. Efficient routing and rerouting of solid waste collection vehicles can decrease labor, equipment, and fuel costs.

4 ❖ HIGHLIGHTS (continued)

Implementing the collection and transfer system involves several steps. (p. 4-32)	Implementing a collection and transfer system involves the following activities: • finalizing and modifying the system management plan • purchasing and managing collection and transfer equipment • hiring and training personnel • developing and managing contracts with labor unions and private collection companies • providing information to the public • constructing and operating transfer, administrative, and maintenance facilities.
Good personnel management is crucial. (p. 4-34 — 4-36)	As in all organizations, good personnel management is essential to an efficient, high-quality waste collection system; hiring and keeping well-qualified personnel is crucial. Because collection jobs are physically demanding, carefully assess each applicant's physical condition. To retain employees, management should provide a safe working environment that emphasizes career advancement, participatory problem solving, and worker incentives.
Safety is a crucial concern. (p. 4-34 — 4-35)	Safety is especially important because waste collection employees encounter many hazards during each workday. As a result of poor safety records, insurance costs for many collection services are high. Frequently encountered hazards include: • busy roads and heavy traffic • rough- and sharp-edged containers that can cause cuts and infections • exposure to injury from powerful loading machinery • heavy containers that can cause back injuries • household hazardous wastes such as herbicides, pesticides, solvents, fuels, batteries, and swimming pool chemicals.
Maintaining good public communication is crucial. (p. 4-36 — 4-37)	Maintaining good communications with the public is important to a well-run collection system. Residents can greatly affect the performance of the collection system by co-operating with set-out (how waste is presented for collection) and separation requirements, and by keeping undesirable materials, such as used oil, from entering the collected waste stream.
Successful management requires monitoring the system's costs and performance. (p. 4-37)	Collection and transfer facilities should develop and maintain an effective system for cost and performance monitoring. Just as the goals of a collection program guide its overall directions, a monitoring system provides the short-term feedback necessary to identify the course corrections needed to achieve those goals.

4 COLLECTION AND TRANSFER

DEVELOPING A SOLID WASTE COLLECTION AND TRANSFER SYSTEM

This chapter presents an 11-component process (see Table 4-1) for developing a collection system to meet a community's needs.

Collection programs in different communities vary greatly depending on the waste types collected, the characteristics of the community, and the preferences of its residents. Often, different collection equipment, methods, or service providers are required in the same community to serve different customers (single-family, multi-family and commercial) or to collect different materials (solid waste and recyclables) from the same customers.

Collection and transfer systems are often complex and difficult to design because many factors must be considered and a wide range of collection and transfer options are available. To simplify system design and modifications, this section presents an 11-component process for developing or modifying a collection system to best meet a community's needs. Table 4-1 provides an outline of the process, which can be adapted to meet a community's specific needs. Suggested procedures for completing each step is provided in the following sections.

Table 4-1

Key Steps in Developing or Modifying a Waste Collection and Transfer System

1. Define community goals and constraints.
2. Characterize waste generation and service area.
3. Determine public and private collection and transfer options.
4. Determine system funding structure.
5. Identify waste preparation and collection procedures.
6. Identify collection equipment and crew size requirements.
7. Evaluate transfer needs and options.
8. Evaluate collection and transfer alternatives.
9. Develop collection routes and schedules.
10. Implement the collection system.
11. Monitor system performance; adjust as necessary.

Source: W. Pferdehirt, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, 1994

DEFINING COMMUNITY GOALS AND CONSTRAINTS

Each community should clearly define the goals for its collection system, periodically review the system's performance in meeting those goals, and regularly review and adjust the system's goals to conform to changes in the community's needs. Similarly, constraints should be identified and incorporated in the decision-making process. Some constraints, such as funding, can possibly be adjusted to meet changing needs.

Identifying goals, objectives, and constraints can help guide the planning process. Issues that should be considered include the following:

Evaluating program goals and constraints is an ongoing process influenced by many issues.

- **Level of service:** What level of services is required to meet the community's needs? What materials need to be collected and what are the requirements for separate collection of these materials? What needs and expectations exist with respect to the frequency of pickup and the convenience of set-out requirements for residents?
- **Roles for the public and private sectors:** Is there a policy preference regarding the roles of the public and private sectors in providing collection services for wastes and recyclables? If collection is to be performed by private haulers, should the municipality license, franchise, or contract with haulers?
- **Waste reduction goals:** What are the community's waste reduction goals and what strategies are necessary or helpful in achieving those goals? For example, source reduction and recycling can be facilitated by charging customers according to the volume of wastes discarded, by providing convenient collection of recyclables, and by providing only limited collection of other materials such as yard trimmings and tires.
- **System funding:** What preferences or constraints are attached to available funding mechanisms? Are there limits on the cost of service based on local precedence, tax limits, or the cost of service from alternative sources?
- **Labor contracts:** Are there any conditions in existing contracts with labor unions that would affect the types of collection equipment or operations that can be considered for use? How significant are such constraints and how difficult would they be to modify?

CHARACTERIZING WASTE TYPES, VOLUMES, AND THE SERVICE AREA

Gather data to determine your community's collection needs.

Data concerning waste generator types, volumes of wastes generated, and waste composition should be gathered so that community collection needs can be determined. Estimates of generation and composition can usually be developed through a combination of (1) historical data for the community in question, (2) data from similar communities, and (3) published "typical" values. Adjust data as necessary to correspond as closely as possible to local and current circumstances. See Chapter 3 for further discussion of techniques for estimating waste generation.

City street and block maps should also be obtained to determine information on specific block and street configurations, including number of houses, location of one-way and dead-end streets, and traffic patterns.

PUBLIC AND PRIVATE COLLECTION/TRANSFER: DETERMINING OPTIONS

Study alternative roles for the public and private sectors.

Before or while the technical aspects of the solid waste collection and transfer system are being developed, a municipality should evaluate alternative roles for the public and private sectors in providing collection services. The collection system may be operated by a municipal department, a contracted private firm, one or more competing private firms, or a combination of public and private haulers.

The following terms are commonly used when referring to these different collection systems:

- **Municipal collection:** A municipal agency uses its own employees and equipment to collect solid waste.

- **Contract collection:** A municipal agency contracts with a private collection firm to collect waste. Larger communities may issue multiple collection contracts, each for a different geographic area, type of customer (single-family versus multi-family units), or material collected (recyclables versus refuse).
- **Private collection:** Residents directly engage the services of private collection firms. Some communities using this approach give residents the complete freedom to choose haulers and the level of service provided; some require that all haulers obtain a license to operate from the municipality. This system relies on competition to control prices and quality of service. Other communities, wishing to reduce truck traffic and the costs of service through eliminating duplication of service, allow haulers to competitively bid to provide a specified level of service to residents within a defined "franchise" area. Residents then contract directly with the designated hauler for their area for the price and level of service specified in the hauler's franchise agreement with the municipality.

Each community should carefully evaluate which type of collection system, or combination of systems, will best meet their needs.

The collection system that is most appropriate for a particular community depends on the needs of the community and availability of qualified private collection firms. No single system type is best for all communities. In fact, one community may wish to consider the use of different systems for different customer types or different areas of the community. For example, many municipalities provide municipal service to single-family residences, small apartment buildings and small commercial customers, but require that larger apartment buildings and commercial and industrial customers arrange separately for their collection services.

In addition, municipalities may wish to explore options for working with other nearby communities to provide collection service on a regional basis. Development of a regional collection system can be particularly cost-effective if several small communities are located close to each other and use the same disposal site.

DETERMINING THE SYSTEM FUNDING STRUCTURE

Selecting the method of funding is a key step in developing a solid waste collection system. The goal of a funding plan is to generate the money necessary to pay for collection services. In addition, a well-designed funding method can also help a community achieve its waste reduction and management goals.

Selecting the funding method is a key step.

The three principal alternatives for funding solid waste services are (1) property tax revenues, (2) flat fees, and (3) variable-rate fees. These three methods and their relative advantages and disadvantages are summarized in Table 4-2.

- **Property taxes:** A traditional way of funding solid waste collection is through property taxes, especially in communities where collection has been performed by municipal workers. A principal attraction of this method is its administrative simplicity; no separate system is necessary to bill and collect payments, since funds are derived from moneys received from collection of personal and corporate property taxes.

  Despite its ease of administration, however, communities are increasingly moving away from this funding method, at least as their sole funding source. Many municipalities have shifted to covering part or all of their costs through user fees, largely because of statutorily or politically imposed caps on property tax increases. In addition, municipal officials realize that funding from property taxes provides no incentives to residents to reduce wastes through recycling and source reduction.

Table 4-2

Advantages and Disadvantages of Alternative Funding Mechanisms

Property Taxes

Under this approach, a portion of property tax revenues is used to fund waste collection. Although the tax revenues are collected by the municipality, the funded collection services may be provided by either municipal crews or by a private hauler under contract.

Advantages

- Collection of funds is relatively easy to administer; collected as part of taxes.
- Everyone pays for the system; less incentive for improper disposal by dumping wastes along roadsides or in other people's containers.
- Can be argued that costs are generally distributed according to ability to pay, since owners of expensive properties pay most.

Disadvantages

- Generators have no direct incentive for waste reduction.
- Revenues are hard to adjust to unexpected budget increases, for example, to cover higher tipping fees or fuel costs.
- Generators are unable to reduce their cost of service through waste reduction.
- Actual, total costs of waste services may be difficult to track because personnel, equipment and facilities funded from property taxes may be used for multiple purposes. Often results in understatement of actual costs, and perhaps demand for higher level of service than if costs were apparent.
- Can lead to equity-related objections if commercial and large, multi-family properties are not served by municipal waste collection, but are levied taxes to support it. Similar concerns may arise if tax- exempt property owners receive municipal waste collection.

Flat-Fee Systems

Under flat-fee systems, residents pay a set monthly fee for waste collection. The fee may be collected by the municipality or by a private hauler.

Advantages

- Relatively easy to administer; same fee for all.
- Usually easier to adjust fees than change tax assessments.
- If collection is by private sector, local government does not need to get involved in collection of service fees.
- Cost of waste collection is not counted against property tax limits.

Disadvantages

- Fees are often earmarked for a separate fund used exclusively for solid waste services. Moneys in such funds are less often subject to re-appropriation by elected officials than property tax revenues.
- If fees are set to recover full cost of waste services, elected officials and the public can make more informed choices about services to be provided.
- Some residents may try to evade cost of service by dumping wastes along roads, streams, alleys, etc.
- Fees can be more difficult than taxes to collect.
- Flat fees do not reward waste reduction.
- Fee-based systems generally require poorer residents to pay more than they would under systems funded by property taxes.

Variable-Rate Systems

Under a variable-rate system, residents are charged on a sliding scale, depending on how much waste they set out for collection. Charges can vary by the week, depending on the amount set out by a resident for that particular collection day, or residents can "subscribe" for a selected level of service (e.g., one 30-gallon can per week).

Advantages

- Provide direct economic incentives that motivate residents to generate less waste.
- Let generators choose the amount of service they purchase.
- Usually increase participation rates and collected quantities for recycling collection programs.
- Usually lead to greater level of awareness among residents when making purchasing decisions that affect waste generation.
- Typically result in more on-site management of yard trimmings through composting and leaving clippings on lawns.
- Except for relative ease of administration, have all other advantages of flat-fee systems.

Disadvantages

- Can be complicated to administer; must have method of computing charges, or distributing bags or stickers.
- When rates are based on volume customers sometimes compact wastes excessively, which can cause overweight containers and higher bag breakage.
- Contaminants in recyclables can increase as residents try to minimize waste collection charges. Recycling workers should diligently prevent wastes from being collected with recyclables.
- Often require enforcement programs, at least initially, to prevent illegal dumping.
- Can be difficult to project anticipated revenues; if contracting with a hauler for service, municipality may need to guarantee minimum level of revenues from fees.
- Under a pure variable-rate system, large families will typically pay more than under flat fee or property-tax-funded systems. Can be especially hard on poorer, large families. Effects can be decreased through a payment assistance plan or through a hybrid funding approach that covers part of collection costs from taxes or a flat fee.

Hybrid Funding Methods

Hybrid approaches use a combination of the above methods to fund collection services. For example, variable-rate systems often pay for a portion of costs through a base rate or taxes. Advantages and disadvantages depend on the specific components of the selected funding approach.

Source: W. Pferdehirt, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, 1994

Whereas this was generally tolerated when disposal was relatively cheap, the increased cost to properly manage wastes has caused many communities to find ways to give meaningful pricing signals and incentives to residents.

- **Flat fees:** Flat fees are a common method for funding collection in many communities served by private haulers and in many municipalities where a separate authority or special purpose fund is used for solid waste services. Although this method does a better job than property taxes in communicating the real cost of solid waste services, it still does not provide an incentive for reducing wastes.
- **Variable-rate fees:** With a variable-rate fee system, generators pay in proportion to the amount of wastes they set out for collection. Variable rates are also called unit rates and volume-based rates. Variable-rate systems typically require that residents purchase special bags or stickers, or they offer generators a range of service subscription levels. When bags or stickers are used, their purchase price is set high enough to cover most or all program costs, including costs for bags and stickers and for an accounting system.

  Systems that offer generators a range and choice of subscription levels have less administrative complexity than systems that use bags and stickers. However, when generators use bags and stickers, they may be more aware of how much waste they are producing and, therefore, have more incentive to reduce it. In addition, by using smaller or fewer bags or fewer stickers, generators can realize savings from their source reduction efforts immediately.

Communities can combine elements from different funding methods to meet their specific needs.

Sometimes communities combine various elements of the above funding methods to form a hybrid system specially tailored for their communities. Many variable-rate programs are adapted to mute the potential negative impacts of such systems. For example, a basic level of service offering a certain number of bags or one can per week could be provided to all residents and paid for from property taxes. Generators could then be required to place any additional wastes in special bags sold by the municipality.

Municipalities that choose to provide collection, either on their own or through a municipal contract with a hauler, might find it advantageous to segregate solid waste funds in an enterprise account. With this method, costs and revenues for solid waste services are kept separate from other municipal functions, and mangers are given authority and responsibility to operate with more financial independence than when traditional general revenue departments are used. Some local governments have found that this approach increases the accountability and cost-effectiveness of their solid waste operations.

Accurately tracking the full costs of waste collection services is crucial.

The importance of accurately tracking the full costs of waste collection services cannot be overstated. For most communities, the costs of collecting wastes or recyclables are significantly higher than the costs of disposal or processing. Accurate cost accounting can provide managers with the information necessary to compare performance with other similar communities and the private sector and to identify opportunities for improving efficiency. Some states, including Florida, Indiana, and Georgia, have enacted laws requiring “full-cost accounting” of waste services by municipalities. Full-cost accounting provides residents and decision makers with more complete information on waste collection by including indirect costs, such as administration, billing, and legal services along with such direct costs as labor, equipment, tipping fees, and supplies. In communities where garbage collection is funded from property taxes, this information helps residents understand that “free” garbage collection is, in reality, not possible. Using full-cost accounting, many communities have demonstrated that the costs of recycling collection and processing are less than those for solid waste collection and disposal. However, even when the costs of recycling are shown to be greater, the information helps communities better understand and weigh the cost / benefit tradeoffs of the alternative systems being considered.

IDENTIFYING WASTE PREPARATION AND COLLECTION PROCEDURES

Decisions about how residents prepare waste for pickup and which methods are used to collect it affect each other and must be coordinated to achieve an efficient, effective system. For example, a community may decide to use self-loading compactor trucks in certain neighborhoods. As a result, residents will have to prepare wastes by placing them in containers that fit the trucks' container-lifting mechanisms. These decisions about vehicle and container types would affect the selection of crew size, allowing a smaller crew than manual systems would.

Solid Waste Set-Out Requirements

How residents prepare waste for collection affects program costs. Table 4-3 describes different set-out options.

To establish uniform and efficient collection, communities normally develop guidelines and enact ordinances that specify how residents must prepare solid waste and recyclables for collection. Although the requirements vary from one community to another, set-out requirements usually address the types of containers to be used, separation of recyclables or other wastes for separate collection, how frequently materials are collected, and where residents are to set materials out for collection.

Storage Container Specifications

Many municipalities enact ordinances that require using certain solid waste storage containers. Most important, containers should be functional for the amount and types of materials they must hold and the collection vehicles used. Containers should also be durable, easy to handle, and economical, as well as resistant to corrosion, weather, and animals.

In residential areas where refuse is collected manually, either plastic bags or standard-sized metal or plastic containers are typically required for waste storage. Many cities prohibit the use of other containers, such as cardboard boxes or 55-gallon drums, because they are difficult to handle and increase the chance of worker injury.

If cans are acceptable, they should be weatherproof, wider at the top than bottom, fitted with handles and a tightly fitting lid, and maintained in good condition. Many municipalities limit cans to 30-35 gallons or to a maximum specified total weight. Some municipalities also limit the total number of containers that will be collected under normal service; sometimes additional fees are charged for additional containers.

If plastic bags are acceptable, they must be in good condition and tied tightly. Some communities require that bags meet a specified minimum thickness (for example, 2 mils) to reduce the propensity for tearing during handling. Some programs require the use of bags because they do not have to be emptied and returned to the curb or backyard and are therefore quicker to collect than cans.

Some communities require that residents purchase metered bags or stickers so that residents pay fees on a per-container basis. The price of the bags or stickers usually includes costs for waste collection and disposal services. A related option is to charge different rates for various sizes of cans or other containers. Communities that also collect recyclables usually do so at no, or reduced, cost to residents as a financial incentive for recycling instead of disposal.

When automatic or semiautomatic collection systems are used, solid waste containers must be specifically designed to fit the truck-mounted loading mechanisms. Waste-storage containers used in such systems typically range from 1 to 30 cubic yards in size. Automatically loading compactor trucks are commonly used to pick up waste from apartment buildings and commercial establishments.

Automatic and semiautomatic collection systems are also being used increasingly in single-family neighborhoods to reduce costs. For example, the community of Sarasota, Florida switched from manual collection to semiautomatic collection. Under the manual collection system, the city provided backyard and curbside service using 8-cubic-yard packer bodies, which were emptied at a transfer station. Under the new semiautomatic system, the community provides customers with 90-gallon carts which they wheel to the curb. The carts are then emptied automatically into 17-cubic-yard trucks. The trucks transport wastes directly to the disposal site; this eliminates the need for a transfer station. As a result of this process modification, Sarasota has reduced the number of crew members per truck from 3 to 2 and the total number of routes from 14 to 11.

Solid Waste Separation Requirements

Recycling programs usually require residents to separate waste for collection.

Communities may wish to collect some portions of solid waste separately, which requires that residents separate wastes before the collection. As more communities implement recycling programs, mandatory separation of recyclable materials such as paper, cardboard, glass, aluminum, tin, and plastic is also increasing. Communities may also require residents to separate yard trimmings, bulky items, and household hazardous wastes for separate collection or drop-off by residents. Bulky items are usually placed at the same point of collection as other solid wastes. Recently, some U.S. communities have begun to test wet / dry collection systems, in which “wet” organic wastes acceptable for composting are collected separately from “dry” wastes, which will be sorted for the recovery of recyclables. Phoenix, Arizona is the first large U.S. city to experiment with a city-wide wet / dry collection system.

Frequency of Collection

Communities can select the level of services they wish to provide by choosing how often to collect materials and the point from which materials will be collected at each residence. The greater the level of service, the more costly the collection system will be to operate.

Many factors together determine the appropriate frequency of collection for each community.

Factors to consider when setting collection frequency include the cost, customer expectations, storage limitations, and climate. Most municipalities offer collection once or twice a week, with collection once a week being prevalent. Crews collecting once per week can collect more tons of waste per hour, but are able to make fewer stops per hour than their twice-a-week counterparts. A USEPA study found that once-a-week systems collect 25 percent more waste per collection hour, while serving 33 percent fewer homes during that period. Personnel and equipment requirements were 50 percent higher for once-a-week collection (USEPA 1974a). Some communities with hot, humid climates maintain twice-a-week service because of health and odor concerns.

Pick-up Points for Collection

In urban and suburban areas, refuse is generally collected using curbside or alley pickup. Backyard service, which was more common in the past, is still used by some communities. Table 4-3 describes these collection methods and the advantages and disadvantages of each.

As shown in the table, curbside / alley service is more economical but requires greater resident participation than backyard service. In fact, according to Hickman (1986), the productivity of backyard systems is about one-half that of curbside or alley systems. Therefore, as municipal budgets have tightened and service costs increased, most municipalities have chosen or switched to

Table 4-3
Advantages and Disadvantages of Alternative Pick-Up Points for Collecting Solid Wastes

Curb-side/Alley Collection

Residents place containers to be emptied at curb or in alley on collection day. Collection crew empties containers into collection vehicle. Resident returns containers to their storage location until next scheduled collection time.

Advantages:

- Crew can move quickly.
- Crew does not enter private property, so fewer accidents and trespassing complaints arise.
- This method is less costly than backyard collection because it generally requires less time and fewer crew members.
- Adaptable to automated and semi-automated collection equipment.

Disadvantages:

- On collection days, waste containers are visible from street.
- Collection days must be scheduled.
- Residents are responsible for placing containers at the proper collection point.

Backyard Set Out - Set Back Collection

Containers are carried from backyard to curb by a special crew and emptied by the collection crew. The special crew then transports the containers back to their original storage location.

Advantages:

- Collection days need not be scheduled.
- Waste containers are not usually visible from street.
- Use of additional crew members reduces loading time as compared to backyard carry method.

Disadvantages

- Because crews enter private property, more injuries and trespassing complaints are likely.
- The method is more time-consuming.
- Residents are not involved and requires more crew members than curb-side/alley collection.
- This is more costly than curb-side/alley collection because additional crews are required.

Backyard Carry Collection

In this method, collection crews enter property to collect refuse. Containers may be transported to the truck, emptied and returned to their original storage location, or emptied into a tub or cart and transported to the vehicle so that only one trip is required.

Advantages:

- Collection days need not be scheduled.
- Waste containers are not usually visible from street.
- Residents are not involved with container setout or movement.
- This method requires fewer crew members than set out/ set back method.

Disadvantages:

- Because crew enters private property, more injuries and trespassing complaints are likely.
- This approach is more time-consuming than curb-side/alley or set back method.
- Spills may occur where waste is transferred.

Drop Off at Specified Collection Point

Residents transport waste to a specified point. This point may be a transfer station or the disposal site.

Advantages:

- Drop-off is the least expensive of methods.
- Offers reasonable strategy for low population densities.
- This method involves low staffing requirements.

Disadvantages:

- Residents are inconvenienced.
- There is increased risk of injury to residents.
- If drop-off site is unstaffed, illegal dumping may occur.

Source: American Public Works Association, Institute for Solid Wastes. 1975. *Solid Waste Collection Practice*. 4th ed., Chicago

Pick-up strategies must be carefully planned.

curbside/alley collection. However, some municipalities have traditionally offered backyard service to residents and decide to continue offering this service.

Rural areas face special challenges because of low population densities and limited budgets for solid waste operations. When pick-up service is offered in rural areas, residents usually are required to place bags or containers of wastes near their mailboxes or other designated pick-up points along major routes. Other municipalities prefer a drop-off arrangement, such as that described in Table 4-3. In such cases, wastes are dropped off at a smaller transfer station (described below). Drop-off service is much less expensive than a collection service but also less convenient for residents.

Some municipalities also offer collection service to larger apartment buildings and commercial establishments. In other communities, service to these customers is provided by private collection companies. In general, wastes from such buildings are stored in dumpsters or roll-off containers and collected using either front-loading compactors or roll-off hoist trucks, respectively.

DETERMINING COLLECTION EQUIPMENT AND CREW SIZE

Selecting Collection Equipment

Equipment Types

Regulations, crew preferences, and many other factors must be considered.

Numerous types of collection vehicles and optional features are available. Manufacturers are continually refining and redesigning collection equipment to meet changing needs and to apply advances in technology. Trends in the collection vehicle industry include increased use of computer-aided equipment and electronic controls. Now, some trucks even have onboard computers for monitoring truck performance and collection operations.

Truck chassis and bodies are usually purchased separately and can be combined in a variety of ways. When selecting truck chassis and bodies, municipalities must consider regulations regarding truck size and weight. An important objective in truck selection is to maximize the amount of wastes that can be collected while remaining within legal weights for the overall vehicle and as distributed over individual axles. Also, because they are familiar with equipment, collection crews and drivers should be consulted when selecting equipment that they will be using.

Compactor trucks are by far the most prevalent refuse collection vehicles in use. Widely used for residential collection service, they are equipped with hydraulically powered rams that compact wastes to increase payload and then push the wastes out of the truck at the disposal or transfer facility. These trucks vary in size from 10 to 45 cubic yards, depending on the service application. Compactor trucks are commonly classified as front-loading, side-loading, or rear-loading, depending on where containers are emptied into the truck.

Before compactor trucks were developed, open and closed noncompacting trucks were used to collect solid waste. Although these trucks are relatively inexpensive to purchase and maintain, they are inefficient for most collection application because they carry a relatively small amount of waste, and workers must lift waste containers high to dump the contents into the truck. Noncompacting trucks are still used for collecting bulky items like furniture and appliances or other materials that are collected separately, such as yard trimmings and recyclable materials. Noncompacting trucks can also be appropriate for small communities or in rural areas. Recently, many new types of noncompacting trucks have been designed specifically for collecting recyclable materials.

Waste set-out requirements, waste quantities, and the physical characteristics of the collection routes are likely to be key considerations in the selection of collection vehicles. For example, suburban areas with wide streets and little on-street parking may be ideally suited to side-loading automatic collection systems. Conversely, urban areas with narrow alleys and tight corners may require rear loaders and shorter wheelbases.

For large apartment buildings and complexes, and for commercial and industrial applications, hauled-container systems are often used. The roll-off containers used with these systems have capacities of up to 50 cubic yards. They are placed on the waste generator's property, and when full, are transported directly to the transfer / disposal site. Special hoisting trucks and a cable winch or hydraulic arm are required to load the containers.

Criteria for Equipment Selection

Establishing written criteria makes selecting appropriate equipment easier.

To determine specific equipment design information, hauling companies or departments should contact vendors and review existing equipment records. Table 4-4 provides criteria that should be used to determine the most appropriate collection equipment. Municipalities can use these criteria to outline the requirements that equipment must meet and select general equipment types that will be considered.

In addition to the technical requirements listed in Table 4-4, the following cost data should be compared for each truck being considered: initial capital cost, annual maintenance and operation costs, and expected service life. Life-cycle costs should be computed using this information to compare total ownership costs over the expected life of the required vehicles.

Crew Size

The optimum crew size for a community depends on labor and equipment costs, collection methods and route characteristics. Crew sizes must also reflect conditions in contracts with labor unions. As previously mentioned, crew size can have a great effect on overall collection costs.

As collection costs have risen, there has been a trend toward (1) decreasing frequency of collection, (2) increasing requirements on residents to sort materials and transport them to the curb, and (3) increasing the degree of automation used in collection. These three factors have resulted in smaller crews in recent years. Generally, a one-person crew can spend a greater portion of its time in the productive collection of wastes than a two- or three-person crew can. Multiple-person crews tend to have a greater amount of nonproductive time than do single-person crews because nondriving members of the crew may be idle or not fully productive during the haul to the unloading point. Some communities address this problem by requiring that nondrivers perform other duties, such as cleaning alleys, while the driver hauls collected wastes to the disposal or transfer facility.

Crew size greatly affects program costs. Optimum crew size depends on

- *labor/equipment costs*
- *collection methods/routes*
- *labor union contracts.*

Although the one-person crew has the greatest percentage of productive time, many municipalities use larger crews, mainly for three reasons: some trucks (for example, rear-loading packers) do not readily support use of a single-person crew, the municipality wants to provide a higher level of service than one-person crews can provide, or labor contract provisions require more than one person on each crew. These multi-person crews can be efficient if properly trained and provided with suitable performance incentives. In more efficient multiple-person crews, the driver helps with waste loading and the crew carries some containers to the truck instead of driving to each pick-up location.

EVALUATING TRANSFER NEEDS AND OPTIONS

Sometimes, for efficiency or convenience, municipalities find it desirable to transfer waste from collection trucks or stationary containers to larger vehicles

Table 4-4

Factors to Consider in Selecting or Specifying Solid Waste Collection Equipment

Loading Location

Compactor trucks are loaded in either the side, back, or front. Front-loading compactors are often used with self-loading mechanisms and dumpsters. Rear loaders are often used for both self and manual loading. Side loaders are more likely to be used for manual loading and are often considered more efficient than back-loaders when the driver does some or all of the loading.

Truck Body or Container Capacity

Compactor capacities range from 10 to 45 cubic yards. Containers associated with hauled systems generally have a capacity range of 6 to 50 cubic yards. To select the optimum capacity for a particular community, the best tradeoff between labor and equipment costs should be determined. Larger capacity bodies may have higher capital, operating, and maintenance costs. Heavier trucks may increase wear and tear, and corresponding maintenance costs for residential streets and alleys.

Design Considerations:

- The loading speed of the crew and collection method used.
- Road width and weight limits (consider weight of both waste and vehicle).
- Capacity should be related to the quantity of wastes collected on each route. Ideally, capacity should be an integral number of full loads.
- Travel time to transfer station or disposal site, and the probable life of that facility.
- Relative costs of labor and capital.

Chassis Selection

Chassis are similar for all collection bodies and materials collected.

Design Considerations:

- Size of truck body. Important for chassis to be large enough to hold truck body filled with solid waste.
- Road width and weight limitations (also need to consider waste and truck body weight).
- Air emissions control regulations.
- Desired design features to address harsh treatment (e.g., driving slowly, frequent starting and stopping, heavy traffic and heavy loads) include the following: high torque engine, balanced weight distribution, good brakes, good visibility, heavy duty transmission, and power brakes and steering.

Loading Height

The lower the loading height, the more easily solid waste can be loaded into the truck. If the truck loading height is too high, the time required for loading and the potential of injuries to crew members will increase because of strain and fatigue.

Design Considerations:

- Weight of full solid waste containers.
- If higher loading height is being considered, consider an automatic loading mechanism.

Loading and Unloading Mechanisms

Loading mechanisms should be considered for commercial and industrial applications, and for residences when municipalities wish to minimize labor costs over capital costs. A variety of unloading mechanisms are available.

Design Considerations—Loading:

- Labor costs of collection crew.
- Time required for loading.
- Interference from overhead obstructions such as telephone and power lines.
- Weight of waste containers.

Design Considerations—Unloading:

- Height of truck in unloading position. Especially important when trucks will be unloaded in a building.
- Reliability and maintenance requirements of hydraulic unloading system device.

Truck Turning Radius

Radius should be as short as possible, especially when part of route includes cul-de-sacs or alleys. Short wheelbase chassis are available when tight turning areas will be encountered.

Watertightness

Truck body must be watertight so that liquids from waste do not escape.

Safety and Comfort

Vehicles should be designed to minimize the danger to solid waste collection crews.

Design Considerations:

- Carefully designed safety devices associated with compactor should include quick-stop buttons. In addition, they should be easy to operate and convenient.
- Truck should have platforms and good handholds so that crew members can ride safely on the vehicle.
- Cabs should have room for crew members and their belongings.
- Racks for tools and other equipment should be supplied.
- Safety equipment requirements should be met.
- Trucks should include audible back-up warning device.
- Larger trucks with impeded back view should have video camera and cab-mounted monitor screen.

Speed

Vehicles should perform well at a wide range of speeds.

Design Considerations:

- Distance to disposal site.
- Population and traffic density of area.
- Road conditions and speed limits of routes that will be used.

Adaptability to Other Uses

Municipalities may wish to use solid waste collection equipment for other purposes such as snow removal.

Source: W. Pferdehirt, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, 1994

before transporting it to the disposal site. This section discusses how to decide if a transfer facility is necessary to serve the waste collection needs of a community. The section also discusses factors to consider when designing a transfer station and selecting equipment for it.

Communities that provide curbside collection of recyclables may find it necessary to develop a material recovery facility (MRF) to sort and densify materials before they are shipped to markets. MRF siting and design requirements are discussed in Chapter 6.

Evaluating Local Needs for Waste Transfer

Transfer station cost-effectiveness depends on distance of disposal site from the generation area.

10-15 miles is usually the minimum cost-effective distance.

To determine whether a transfer system is appropriate for a particular community, decision makers should compare the costs and savings associated with the construction and operation of a transfer facility. Benefits that a transfer station can offer include lower collection costs because crews waste less time traveling to the site, reduced fuel and maintenance costs for collection vehicles, increased flexibility in selection of disposal facilities, the opportunity to recover recyclables or compostables at the transfer site, and the opportunity to shred or bale wastes prior to disposal. These benefits must be weighed against the costs to develop and operate the facility. Also, transfer facilities can be difficult to site and permit, particularly in urban areas.

Obviously, the farther the ultimate disposal site is from the collection area, the greater the savings that can be realized from use of a transfer station. The minimum distance at which use of a transfer station becomes economical depends on local economic conditions. However, most experts agree that the disposal site must be at least 10 to 15 miles from the generation area before a transfer station can be economically justified. Transfer stations are sometimes used for shorter hauls to accomplish other objectives, such as to facilitate sorting or to allow the optional shipment of wastes to more distant landfills.

Types of Transfer Stations

Many factors influence transfer station design.

The type of station that will be feasible for a community depends on the following design variables:

- required capacity and amount of waste storage desired
- types of wastes received
- processes required to recover material from wastes or prepare it (e.g., shred or bale) for shipment
- types of collection vehicles using the facility
- types of transfer vehicles that can be accommodated at the disposal facilities
- site topography and access.

Following is a brief description of the types of stations typically used for three size ranges:

- small capacity (less than 100 tons/day)
- medium capacity (100 to 500 tons/day)
- large capacity (more than 500 tons/day).

Small to Medium Transfer Stations

Typically, small to medium transfer stations are direct-discharge stations that provide no intermediate waste storage area. These stations usually have drop-off areas for use by the general public to accompany the principal operating areas dedicated to municipal and private refuse collection trucks. Depending on weather, site aesthetics, and environmental concerns, transfer operations of this size may be located either indoors or outdoors.

The type of station determines operator needs.

More complex small transfer stations are usually attended during hours of operation and may include some simple waste and materials processing facilities. For example, the station might include a recyclable materials separation and processing center. Usually, direct-discharge stations have two operating floors. On the lower level, a compactor or open-top container is located. Station users dump wastes into hoppers connected to these containers from the top level.

Smaller transfer stations used in rural areas often have a simple design and are often left unattended. These stations, used with the drop-off collection method, consist of a series of open-top containers that are filled by station users. These containers are then emptied into a larger vehicle at the station or hauled to the disposal site and emptied. The required overall station capacity (i.e., number and size of containers) depends on the size and population density of the area served and the frequency of collection. For ease of loading, a simple retaining wall will allow containers to be at a lower level so that the tops of the containers are at or slightly above ground level in the loading area.

Larger Transfer Stations

Larger transfer stations are designed for heavy commercial use by private and municipal collection vehicles. In some cases, the public has access to part of the station. If the public will have access, the necessary facilities should be included in the design. The typical operational procedure for a larger station is as follows:

1. When collection vehicles arrive at the site, they are checked in for billing, weighed, and directed to the appropriate dumping area. The check-in and weighing procedures are often automated for regular users.
2. Collection vehicles travel to the dumping area and empty wastes into a waiting trailer, a pit, or onto a platform.
3. After unloading, the collection vehicle leaves the site. There is no need to weigh the departing vehicle if its tare (empty) weight is known.
4. Transfer vehicles are weighed either during or after loading. If weighed during loading, trailers can be more consistently loaded to just under maximum legal weights; this maximizes payloads and minimizes weight violations.

The advantages and disadvantages of transfer station types are provided in Table 4-5.

Several different designs for larger transfer operations are common, depending on the transfer distance and vehicle type. Most designs fall into one of the following three categories: (1) direct-discharge noncompaction stations, (2) platform / pit noncompaction stations, or (3) compaction stations. The following paragraphs provide information about each type, and Table 4-5 presents the advantages and disadvantages of each.

Direct-Discharge Noncompaction Stations

Direct-discharge noncompaction stations are generally designed with two main operating floors. In the transfer operation, wastes are dumped directly from collection vehicles (on the top floor), through a hopper, and into open-top trailers on the lower floor. The trailers are often positioned on scales so that dumping can be stopped when the maximum payload is reached. A stationary knuckleboom crane with a clamshell bucket is often used to distribute the waste in the trailer. After loading, a cover or tarpaulin is placed over the trailer top. These stations are efficient because waste is handled only once. However, some provision for waste storage during peak time or system interruptions should be developed. For example, excess waste may be emptied and temporarily stored on part of the tipping floor. Facility permits often restrict how long wastes may be stored on the tipping floor (usually 24 hours or less).

Platform/Pit Noncompaction Stations

In platform or pit stations, collection vehicles dump their wastes onto a floor or area where wastes can be temporarily stored, and, if desired, picked through for recyclables or unacceptable materials. The waste is then pushed into open-top trailers, usually by front-end loaders. Like direct discharge stations, platform stations have two levels. If a pit is used, the station has three levels. A major advantage of these stations is that they provide temporary storage, which allows peak inflow of wastes to be leveled out over a longer period. Although construction costs for this type of facility are usually higher because of the increased floor space, the ability to temporarily store wastes al-

Table 4-5

Advantages and Disadvantages of Transfer Station Types

Direct Dump Stations

Waste is dumped directly from collection vehicles into waiting transfer trailers.

Advantages:

- Because little hydraulic equipment is used, a shut-down is unlikely.
- Minimizes handling of wastes.
- Relatively inexpensive construction costs.
- Drive-through arrangement of transfer vehicles can be easily provided.
- Higher payloads than compactor trailers.

Disadvantages:

- Requires larger trailers than compaction station.
- Dropping bulky items directly into trailers can damage trailers.
- Minimizes opportunity to recover materials.
- Number and availability of stalls may not be adequate to allow direct dumping during peak periods.
- Requires bi-level construction.

Pit or Platform Noncompaction Stations

Waste is dumped into a pit or onto a platform and then loaded into trailers using waste handling equipment.

Advantages:

- Convenient and efficient waste storage area is provided.
- Uncompacted waste can be crushed by bulldozer in pit or on platform.
- Top-loading trailers are less expensive than compaction trailers.
- Peak loads can be handled easily.
- Drive-through arrangement of transfer vehicles can be easily provided.
- Simplicity of operation and equipment minimizes potential for station shutdown.
- Can allow recovery of materials.

Disadvantages:

- Higher capital cost, compared to other alternatives, for structure and equipment.
- Increased floor area to maintain.
- Requires larger trailers than compaction station.

Hopper Compaction Station

Waste is unloaded from the collection truck, through a hopper, and loaded into an enclosed trailer through a compactor.

Advantages:

- Uses smaller trailers than non-compaction stations uncompacted.
- Extrusion/"log" compactors can maximize payloads in lighter trailers.
- Some compactors can be installed in a manner that eliminates the need for a separate, lower level for trailers.

Disadvantages:

- If compactor fails, there is no other way to load trailers.
- Weight of ejection system and reinforced trailer reduces legal payload.
- Capital costs are higher for compaction trailers.
- Compactor capacity may not be adequate for peak inflow.
- Cost to operate and maintain compactors may be high.

Push Pit Compaction Station

Waste is unloaded from the collection truck into a push pit, and then loaded into an enclosed trailer through a compactor.

Advantages:

- Pit provides waste storage during peak periods.
- Increased opportunity for recovery of materials.
- All advantages of hopper compaction stations.

Disadvantages:

- Capital costs for pit equipment are significant.
- All other disadvantages of hopper compaction stations.

Source: W. Pferdehirt, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, 1994

lows the purchase of fewer trucks and trailers, and can also enable facility operators to haul at night or other slow traffic periods. These stations are usually designed to have a storage capacity of one-half to two days' inflow.

Compaction Stations

Compaction transfer stations use mechanical equipment to densify wastes before they are transferred. The most common type of compaction station uses a hydraulically powered compactor to compress wastes. Wastes are fed into the compactor through a chute, either directly from collection trucks or after intermediate use of a pit. The hydraulically powered ram of the compactor pushes waste into the transfer trailer, which is usually mechanically linked to the compactor.

Other types of equipment can be used to compact wastes. For example, wastes can be baled for shipment to a balefill or other disposal facility. Baling is occasionally used for long-distance rail or truck hauling. Alternatively, some newer compactors produce an extruded, continuous "log" of wastes, which can be cut to any length. Bales or extruded wastes can be hauled with a flat-bed truck or a trailer of lighter construction because, unlike with a traditional compactor, the side walls of the trailer do not need to restrain the wastes as the hydraulic ram pushes them.

Compaction stations are used when (1) wastes must be baled for shipment (e.g., rail haul) or for delivery to a balefill, (2) open-top trailers cannot be used because of size restrictions such as viaduct clearances, and (3) site topography or layout does not accommodate a multi-level building conducive to loading open-top trailers. The main disadvantage to a compaction facility is that the facility's ability to process wastes is directly dependent on the operability of the compactor. Selection of a quality compactor, regular preventive maintenance of the equipment, and prompt availability of service personnel and parts are essential to reliable operation.

Transfer Station Design Considerations

This section discusses factors that should be considered during station design. In general, these factors were developed for designing large stations, but many also apply to smaller transfer stations.

Goals of transfer station design should include:

- *efficient waste handling*
- *equipment and building durability*
- *simple operating scheme*
- *flexibility to modify facility.*

Table 4-6 provides transfer station design considerations.

The main objective in designing a transfer station should be to facilitate efficient operations. The operating scheme should be as simple as possible; it should require a minimum of waste handling, while offering the flexibility to modify the facility when needed. Equipment and building durability are essential to ensure reliability and minimize maintenance costs. With modification, the facility should be capable of handling all types of wastes.

Site Location and Design Criteria

Local residents are most likely to accept the facility if the site is carefully selected, the buildings are designed appropriately for the site, and landscaping and other appropriate site improvements are made. These design features should be accompanied by a thorough plan of operations. When selecting a site, municipalities should consider the following factors:

- **Proximity to waste collection area:** Proximity to the collection area helps to maximize savings from reduced hauling time and distance.
- **Accessibility of haul routes to disposal facilities:** It should be easy for transfer trucks to enter expressways or other major truck routes, which reduces haul times and potential impacts on nearby residences and businesses. When considering sites, determine if local road improvements will be necessary, and if so, whether they will be economically and technically feasible. Accessibility to rail lines and waterways may allow use of rail cars or barges for transfer to disposal facilities.

- **Visual impacts:** The transfer station should be oriented so that transfer operations and vehicle traffic are not readily visible to area residents. To a great extent, visibility can be restricted if the site is large enough. The area required will depend on vehicle traffic and storage needs, necessary buffer areas, and station layout and capacity.
- **Site zoning and design requirements:** Municipalities should confirm that the proposed use meets the site zoning requirements. In addition, the local site plan ordinance should be reviewed to identify restrictions that could affect design, such as building height and setback, and required parking spaces.
- **Proximity to utility tie-ins:** The transfer station may require the following utility services: electricity and gas, water (for domestic use and fire fighting), telephone, and sanitary and storm sewers. Station designers should determine the cost of connecting to these utilities and the continuing service charges associated with them.

In some cases, municipalities may wish to consider the construction of more than one transfer station. For example, two transfer stations may be economically preferable if travel times from one side of the city to the other are excessive.

Site permitting for a transfer station can be time-consuming—begin the process as soon as a site is selected.

One of the most time-consuming aspects of transfer facility design is site permitting. The permitting process should, therefore, be started as soon as a suitable site is selected.

States usually require permits, and some local governments may require them as well. The project team should work closely with regulatory agency staff to determine design and operating requirements, and to be sure that all submittal requirements and review processes are understood. Table 4-6 summarizes additional considerations for site design.

Building Design

Whenever putrescible wastes are being handled, larger transfer stations should be enclosed. Typically, transfer station buildings are constructed of concrete, masonry or metal. Wood is not generally desirable because it is difficult to clean, is less durable, and is more susceptible to fire damage. Key considerations in building design include durability of construction, adequate size for tipping and processing requirements, minimization of column and overhead obstructions to trucks, and flexibility and expandability of layout. Table 4-7 provides a summary of factors that should be considered as part of the building design.

Transfer Station Sizing

The transfer station should have a large enough capacity to manage the wastes that are expected to be handled at the facility throughout its operating life. Factors that should be considered in determining the appropriate size of a transfer facility include:

- capacity of collection vehicles using the facility
- desired number of days of storage space on tipping floor
- time required to unload collection vehicles
- number of vehicles that will use the station and their expected days and hours of arrival (design to accommodate *peak* requirements)
- waste sorting or processing to be accomplished at the facility
- transfer trailer capacity
- hours of station operation
- availability of transfer trailers waiting for loading

Table 4-6
Transfer Station Site Design Considerations

Office Facilities

- Space should be adequate for files, employee records, and operation and maintenance information.
- Office may be in same or different building than transfer operation.
- Additional space needed if collection and transfer billing services included.

Employee Facilities

- Facilities including lunchroom, lockers, and showers should be considered for both transfer station and vehicle personnel.

Weighing Station

- Scales should be provided to weigh inbound and outbound collection vehicles and transfer vehicles as they are being loaded or after loading.
- Number of scales depends on traffic volume. Volume handled by one scale depends on administrative transaction time, type of equipment installed, and efficiency of personnel. A rough rule-of-thumb estimate for collection vehicle scales is about 500 tons/day. Another estimate that can be used for design purposes is a weighing time of 60 to 90 seconds/vehicle.
- Length and capacity of scales should be adequate for longest, heaviest vehicle. Different scales can be used for collection and transfer vehicles. Typical scale lengths are 60 to 70 feet. Typical capacities are 120,000 to 140,000 pounds.
- Computerized scale controls and data-recording packages are becoming increasingly common. Computerized weighing systems record tare weight of vehicle and all necessary billing information.

On-site Roads and Vehicle Staging

- If the public will use the site, separate the associated car traffic from the collection and transfer truck traffic
- Site roads should be designed to accommodate vehicle speed and turning characteristics. For example, pavement should be wider on curves than in straight lanes and have bypass provision on operational areas.
- Ramp slopes should be less than 10 percent (preferably 6 percent max. for up-ramp) and have provisions for de-icing, if necessary.
- The road surface should be designed for heavy traffic.
- Minimize intersections and cross-traffic. Use one-way traffic flow where possible.
- Assure adequate queue space. For design purposes, assume that 25 to 30 percent of vehicles will arrive during each of two peak hours, but check against observed traffic data for existing facilities.

Site Drainage and Earth Retaining Structures

- Drainage structures should be sized to handle peak flow with no disruption in station operation.
- Provide reliable drainage at bottom of depressed ramps.
- For most transfer station designs, earth retaining structures will be required. Elevation differences will vary depending on station design.

Site Access Control

- A chain-link fence, often with barbed wire strands on top, is usually required for security and litter control.
- Consider installing remote video cameras and monitoring screens to watch access gates.
- A single gate is best for controlling security and site access.
- Signs stating facility name, materials accepted, rates, and hours of operation are usually desirable and often required. Ordinances may specify the size of such signs.

Buffer and Landscaping Areas

- Landscaped barriers (berms or shrub buffers) provide noise and visual buffers, and are often required by local ordinance.
- Fast-growing trees that require minimal maintenance are the best choice. Evergreens provide screening throughout the year. Design berms and plantings to meet site-specific screening requirements.

Fuel Supply Facilities

- Fuel storage and dispensing facilities are often located at transfer stations.
- Adequate space to accommodate transfer vehicles is very important.

Water Supply and Sanitary Sewer Facilities

- Water must generally be supplied to meet the following needs: fire protection, dust control, potable water, sanitary facilities use, irrigation for landscaping.
- Fire protection needs usually determine the maximum flow.
- Sanitary sewer services are usually required for sanitary facilities and wash-down water.
- A sump or trap may be required to remove large solids from wash-down water.

.Electricity and Natural Gas

- Electricity is necessary to operate maintenance shop, process and other auxiliary equipment and provide building and yard lighting.
- Natural gas is often required for building heat.

Source: Adapted, in part, from Peluso et al., 1989

- time required, if necessary, to attach and disconnect trailers from tractors, or to attach and disconnect trailers from compactors
- time required to load trailers.

Table 4-8 provides formulas for estimating the required capacity of various types of transfer stations. These formulas should be adapted as necessary for specific applications. The formulas in Table 4-8 do not reflect the effects of using the tipping floor to store wastes.

Consider tradeoffs between capital and operating costs.

When selecting the design capacity of a transfer station, decision makers should consider tradeoffs between the capital costs associated with the station and equipment and the operational costs. The optimum capacity will often be a compromise between the capital costs associated with increased capacity and the costs associated with various operational parameters (for example, collection crew waiting time and hours of operation).

Facility designers should also plan adequate space for waste storage and, if necessary, waste processing. Transfer stations are usually designed to have one-half to two days of storage capacity. The collection vehicle unloading area is usually the waste storage area and sometimes a waste sorting area.

When planning the unloading area, designers should allow adequate space for vehicle and equipment maneuvering. To minimize the space required, the facility should be designed so that collection vehicles back into the unloading position. For safety purposes, traffic flow should be such that trucks back to the left (driver's side). Adequate space should also be available for offices, employee facilities, and other facility-related activities.

Table 4-7

Transfer Station Building Components: Design Considerations

Building Construction

- Usually constructed of concrete masonry or metal.
- If prefabricated metal, building will typically be constructed of multiples of 20- to 25-foot bays.
- Clear-span construction is desirable so that vehicles and equipment do not need to maneuver around columns. Typically, frame will be steel for smaller buildings and steel truss for larger ones.
- Collection vehicles must be able to unload within the building. Generally, most vehicles require 25 to 30 feet clearance. More than 25 to 30 feet may be required for dump trailers.
- Design for flexibility and expendability.

Doors

- Number of openings depends on number of trucks unloading per hour at a peak or compromise time.
- Door placement should minimize effects of wind in contributing to litter and odor problems. Door placement should also minimize visual exposure of tipping operations to neighbors and passersby.
- Door supports should be protected by bollards.
- If possible, doors should be high enough that trucks can be driven through door openings while in full-unloading position. Typically, this requires 25 feet or more of vertical clearance. If damage is possible, provide driver-warning mechanism (e.g., hanging pipe that will hit truck before door).
- Wide doors (min. 16 ft.) improve operations and limit damage to door jambs.
- To eliminate door damage, leave one side of building open.

Floors

- Floors receive considerable wear from various transfer operations.
- To control wear, floors are often topped with a granolithic topping (1 to 2 inches). A less expensive, but less durable option is to use a shake-on metallic hardener for the concrete floor.

Material Recovery

- Include space and equipment for recovery of recyclables.
- Address needs for receiving and storing special materials like household hazardous wastes, appliances, used oil, or tires.

Dust Control

- Dust control should be provided.
- Typical systems include wet-spray systems, dust collection equipment and good ventilation.

Safety Equipment

The necessary safety equipment, equipment shut-off switches, and emergency exit signs should be included.

Maintenance and Clean Up Access

Provide high-pressure hoses for wash-down. Drains should have screens that can be easily cleaned.

Source: Adapted partially from Peluso et al., 1989

Additional Processing Requirements

Waste transfer stations can include additional functions, including

- *waste shredding and baling*
- *recovery of recyclable and compostable materials.*

Solid waste transfer facilities can be designed to include additional waste processing requirements. Such processes can include waste shredding or baling, or the recovery of recyclable or compostable materials.

At a minimum, transfer facilities should provide a sufficient area for the dump-and-pick recovery of targeted recyclables. For example, haulers servicing businesses usually reserve an area of the floor where loads rich in old corrugated containers can be deposited. Laborers then pick through the materials to remove the corrugated containers for recycling. Dump-and-pick operations are a low-capital way to begin the recovery of recyclables, but they are hard on workers' backs and inefficient for processing large volumes of materials.

Newer transfer facilities often include mechanically assisted systems to facilitate the recovery of recyclables. Some facilities use only conveyors to move the materials past a line of workers who pick designated materials from the conveyor and drop the sorted material into a bin or onto another conveyor. Other facilities use mechanical methods to recover certain materials; for example, a magnetic drum or belt can be used to recover tin cans and other ferrous metals, and eddy current separators can be used to remove aluminum.

Shredders or balers are sometimes used to reduce the volume of wastes requiring shipment or to meet the requirements of a particular landfill where wastes are being sent. Shredders are sometimes used for certain bulky wastes like tree trunks and furniture. Solid waste facilities using shredders must take special precautions to protect personnel and structures from explosions caused by residual material in fuel cans and gas cylinders. Commonly used measures include inspecting wastes before shredding, explosion suppression systems, wall or roof panels that blow out to relieve pressure, and restricted access to the shredder area. If considering a combined recyclable material processing and transfer station, municipalities should also refer to Chapter 6.

Table 4-8

Formulas for Determining Transfer Station Capacity

Pit Stations

Based on rate at which wastes can be unloaded from collection vehicles:

$$C = P_c \times (L/W) \times (60 \times H_w/T_c) \times F$$

Based on rate at which transfer trailers are loaded:

$$C = (P_t \times N \times 60 \times H_t)/(T_t + B)$$

Direct Dump Stations

$$C = (N_n \times P_t \times F \times 60 \times H_w)/ [((P_t/P_c) \times (W/L_n)) \times T_c + B]$$

Hopper Compaction Stations

$$C = (N_n \times P_t \times F \times 60 \times H_w)/[(P_t/P_c \times T_c) + B]$$

Push Pit Compaction Station

$$C = (N_p \times P_t \times F \times 60 \times H_w)/[(P_t/P_c \times W/L_p \times T_c) + B_c + B]$$

where:

C	= Station capacity (tons/day)
P_c	= Collection vehicle payload (tons)
L	= Total length of dumping space (feet)
W	= Width of each dumping space (feet)
H_w	= Hours per day that waste is delivered
T_c	= Time to unload each collection vehicle (minutes)
F	= Peaking factor (ratio of number of collection vehicles received during an average 30-minute period to the number received during a peak 30-minute period)
P_t	= Transfer trailer payload (tons)
N	= Number of transfer trailers loading simultaneously
H_t	= Hours per day used to load trailers (empty trailers must be available)
B	= Time to remove and replace each loaded trailer (minutes)
T_t	= Time to load each transfer trailer (minutes)
N_n	= Number of hoppers
L_n	= Length of each hopper (feet)
L_p	= Length of push pit (feet)
N_p	= Number of push pits
B_c	= Total cycle time for clearing each push pit and compacting waste into trailer

Source: Schaper, 1986

Transfer Vehicles

Although most transfer systems use tractor trailers for hauling wastes, other types of vehicles are sometimes used. For example, in collection systems that use small satellite vehicles for residential waste collection, the transfer (or "mother") vehicle could simply be a large compactor truck. At the other extreme, some communities transport large quantities of wastes using piggyback trailers, rail cars, or barges.

The following discussion presents information on truck and rail transfer vehicles. Although smaller vehicles may also be used for transfer, their use is more typically limited to collection.

Trucks and Semitrailers

Carefully consider the community's needs when selecting transfer vehicles.

Trucks and semitrailers are often used to carry wastes from transfer stations to disposal sites. They are flexible and effective waste transport vehicles because they can be adapted to serve the needs of individual communities. Truck and trailer systems should be designed to meet the following requirements:

- Wastes should be transported at minimum cost.
- Wastes must be covered during transport.
- The vehicles should be designed to operate effectively and safely in the traffic conditions encountered on the hauling routes.
- Truck capacity should be designed so that road weight limits are not exceeded.
- Unloading methods should be simple and dependable, not subject to frequent breakdown.
- Truck design should prevent leakage of liquids during hauling.
- The materials used to make the trailers and the design of sidewalls, floor systems, and suspension systems should be able to withstand the abusive loads innate to the handling and hauling of municipal solid wastes.
- The number of required tractors and trailers depends on peak inflow, storage at the facility, trailer capacity, and number of hauling hours. Most direct-discharge stations have more trailers than tractors because empty trailers must be available to continue loading, but loaded trailers can, if necessary, be temporarily parked and hauled later.

It is important to select vehicles that are compatible with the transfer station. There are two types of trailers used to haul wastes: compaction and noncompaction trailers. Noncompaction trailers are used with pit or direct-dump stations, and compaction trailers are used with compaction stations. Noncompaction trailers can usually haul higher payloads than compaction trailers because the former do not require an ejection blade for unloading. Based on a maximum gross weight of 80,000 pounds, legal payloads for compaction trailers are typically 16-20 tons, while legal payloads for open-top live-bottom trailers are 20-22 tons. Possum-belly trailers (which must be tilted by special unloaders at the disposal site) can have legal payloads up to 25 tons.

Transfer vehicles should be able to negotiate the rough and muddy conditions of landfill access roads and should not conflict with vertical clearance restrictions on the hauling route. Table 4-9 discusses additional factors to consider when selecting a transfer trailer.

Rail Cars

Railroads carry only about five percent of transferred wastes in the U.S. (Lueck, 1990). However, as the distance between sanitary landfills and urban areas increases, the importance of railroads in transporting wastes to distant sites also grows. Rail transfer is an option that should be considered, especially when a rail service is available for both the transfer station and the disposal facility, and when fairly long hauling distances are required (50 miles or more). Cities that have recently developed rail transfer systems include Seattle, Washington; Portland, Oregon; and the southeastern Massachusetts region.

The use of rail haul is increasing.

Rail transfer stations are usually more expensive than similarly sized truck transfer stations because of costs for constructing rail lines, installing special equipment to remove and replace roofs of rail cars for loading or to bale wastes, and installing special equipment to unload rail cars at the disposal facility. Transfer trailers, however, can usually transport a payload of only 20-25 tons of waste, whereas a 60-foot boxcar can transport approximately 90 tons of waste. Rail transfer becomes more economically attractive as hauling distances increase, but some communities, such as Cape Cod, Massachusetts, have found short-haul dedicated rail transfer to be economically viable.

Wastes can be transported via rail using either dedicated boxcars or containerized freight systems. Most facilities use boxcars to transport baled wastes. Rail cars with removable roofs can be directly loaded in a rail direct-discharge station. This latter arrangement, which is used at a transfer station

Table 4-9

Transfer Truck and Trailer Systems: Design Considerations

Trailer Type

Trailers are classified as either compaction or noncompaction. Typically, compaction trailers are rear-loading, enclosed and equipped with a push-out blade for unloading. In noncompaction trailers, the entire top is usually open for loading. After loading, top doors or tarps cover waste.

Design Considerations:

- Transfer station design usually determines whether to use a compaction or noncompaction trailer.
- Compaction trailers must endure the pressure of the compaction process; therefore they are usually enclosed and reinforced. As a result, they are often heavier than noncompaction trailers.
- Noncompaction trailers are larger and lighter than compaction trailers. They are usually made of steel or aluminum. These trailers usually have a walking floor or a conveyor floor, or they are tipped by a hydraulic platform at the disposal facility.

Trailer Capacity

Typically, capacities range 65 cubic yards for compaction trailers to 125 cubic yards for noncompaction trailers.

Design Considerations:

- Waste densities are usually 400 to 600 pound/cubic yard for compacted wastes, and 275 to 400 pounds/cubic yard for noncompacted wastes.
- Trailers are typically sized to meet legal payload and dimension requirements. Specific requirements vary depending on local regulations.
- Weight depends on degree of compaction and composition of the material.
- Trailers are often sized to be higher than legal height requirements when empty, but lower when full.

Unloading Mechanisms

Some trailers are self-emptying, and others require additional equipment to help with the unloading process. The most common mechanisms are the following:

Push-Out Blade

- Push-out blades are usually used in compaction trailers and sometimes used in noncompaction trailers.
- In compaction trailers, the same blade that is used to compact wastes is used to eject them.
- The blade is relatively simple to operate and can be powered by tractor hydraulic system or by a separate engine. However, items such as tree limbs can wedge under the blade, causing it to jam.

Moving Floor

- Moving floors are common in noncompaction trailers.
- Floor usually has two or more movable sections that extend across the entire width of the trailer; therefore, even if one section breaks, another can empty wastes.
- Floor can typically empty wastes in 6 to 10 minutes.
- Rear of trailer may be larger to expedite unloading.

Hydraulic Lift

- A lift located at the disposal site tips the trailer to an angle that allows discharge of the wastes.
- Time required for unloading operation is about 6 minutes.
- One disadvantage is a possible wait for use of lift. Breakdown of lift seriously impedes ability to receive wastes.

Pull-Off System

- A movable blade or cable slings are placed in front of the load. To empty load, auxiliary equipment (e.g., landfill dozer) pulls the waste out of the trailer.
- The system may require more time than self-unloading trailers because there may be a wait for auxiliary equipment.

Source: W. Pferdehirt, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, 1994

in Yarmouth, Massachusetts, requires special equipment to lift and rotate the rail car at the unloading facility. Containerized systems require double-handling of wastes because wastes must first be loaded into the containers and the containers then loaded onto rail cars; this process must be reversed at the destination. Therefore, handling costs usually prohibit the use of containerized shipment unless the transfer station or disposal facility is not accessible by rail. If the transfer facility or disposal facility is not served by rail, trucks must be used to transport either containers or noncontainerized bales. In this situation, containers are usually less expensive to handle than are bales; also, bales become susceptible to breakage with increased handling.

When evaluating a potential rail transfer system, decision makers should consider environmental impacts and potential opposition from towns between the transfer facility and the disposal facility. Rail cars should be covered and kept clean, and shipment should be scheduled to minimize en-route delays.

EVALUATING COLLECTION AND TRANSFER ALTERNATIVES

Defining System Alternatives

After options are identified, further evaluation of system-wide alternatives is needed.

After appropriate options for collection, equipment, and transfer have been identified, various combinations of these elements should be examined to define system-wide alternatives for further analysis. Each alternative should be a unique configuration of all collection and transfer elements. For example, a proposed system might consist of the following elements:

- A weekly collection of mixed solid wastes using 30-cubic-yard rear-loading compactors and two-person crews. Wastes would be transported directly to the disposal site.
- A monthly collection of bulky items using an open truck and a one-person crew. Collection would be the same day as regular waste collection.
- A weekly curbside collection of mixed recyclables (newspaper, tin cans, plastic, glass, and aluminum) on the same day as regular waste collection. Materials would be collected in a noncompacting truck by a one-person crew and transported to a recycling facility for separation and processing.
- A drop-off facility for collection of tires, used motor oil and batteries.

Comparing Alternative Strategies

Decision makers should evaluate each candidate for its ability to achieve the identified goals for the collection program. Economic analysis will usually be a central focus of the system evaluations. However, to the extent that the alternatives differ in their level of service or other performance parameters, it is important to note such differences so that decision makers understand the economic tradeoffs involved. This initial evaluation will lead to several iterations, with the differences between the alternatives under consideration becoming more narrowly focused with each round of evaluations.

Analyzing Crew and Truck Requirements

The community can use the number of houses per block or route, along with waste density and quantity information, to determine an average quantity of waste generated (in pounds or cubic yards) for all or portions of the service area. This average waste quantity can be used to estimate the number of stops to be serviced per vehicle load (N) as shown in Table 4-10, item 1. The number of services per load and other block configuration data will be used to develop collection routes and schedules. Seasonal variations in generation rates should be considered when estimating staff and equipment needs.

Estimating Time Requirements

Loading Time Requirements

Making accurate time estimates is essential.

For each collection method and crew size being considered, a loading time should be estimated using data from another, similarly configured system, or, if necessary, using a time study of proposed collection procedures. Time studies are usually performed only if historic data is not available for comparable systems and when the potential cost impacts of the decisions at hand warrant the cost of a time study. Table 4-11 lists procedures for a time study. Estimates of the loading time and average generation per household can be used to determine the average time required to fill a truck (see Table 4-10, item 2).

If distances between stops vary significantly, different loading times and total vehicle filling times should be estimated for each area. These estimates and block configuration data are used to determine collection routes.

Hauling Time and Other Travel Time Requirements

To estimate hauling times for collection vehicles, consider the following:

- travel time from the garage to the route at beginning of day

Table 4-10

Calculations for Waste Collection System Design

1. Number of Services/Vehicle Load (N)

   N = (C x D)/W; where,

   C = Vehicle Capacity (cubic yards)

   D = Waste Density (pounds/cubic yard)

   W = Waste Generation/Residence (pounds/service)

2. Time Required to Collect One Load (E)

   E = N x L; where,

   L = Loading Time/Residence, including on-route travel

3. Number of Loads/Crew/Day (n)

   The number of loads (n) that each crew can collect in a day can be estimated based in the workday length (T), and the time spent on administration and breaks (T1), hauling and other travel (T2), and collection routes (T3).

   A) Administrative and Break Time (T1):

   T1 = A + B; where,

   A = Administrative Time (i.e., for meetings, paperwork, unspecified slack time)

   B = Time for Breaks and Lunch

   B) Hauling and Other Travel Time (T2):

   T2 = (n x H) - f + G + J; where,

   n = Number of Loads/Crew/Day

   H = Time to travel to disposal site, empty truck, and return to route

   f = Time to return from site to route

   G = Time to travel from staging garage to route

   J = Time to return from disposal site to garage

   C) Time Spent on Collection Route (T3):

   T3 = n x E

   where variables have been previously defined.

   D) Length of Workday (T):

   T = T1 + T2 +T3

   where T is defined by work rules or policy and equations A through D are solved to find n.

4. Calculation of Number of Vehicles and Crews (K)

   K = (S x F)/(N x n x M); where,

   S = Total number of services in the collection area

   F = Frequency of collection (numbers/week)

   M = Number of workdays/week

5. Calculation of Annual Vehicle and Labor Costs

   Vehicle Costs = Depreciation + Maintenance + Consumables + Overhead + License + Fees + Insurance

   Labor Costs = Driver Salary + Crew Salaries + Fringe Benefits + Indirect Labor + Supplies + Overhead

Source: Adapted from Tchobanoglous et al., 1977

- travel time from the route to the disposal site (include daily traffic fluctuations)
- time spent queuing, weighing, and tipping at the disposal / transfer site
- travel time to the collection route from the site
- travel time returning to the garage at end of day.

To the extent that different alternatives being considered affect collection or transfer time requirements, the impacts on labor, equipment and operating costs should be quantified. Detailed delineation of individual collection routes can wait until after the specific alternative system is selected.

Overall Time Requirements

Time estimates for each option should be computed.

The loading and hauling times can be used to calculate the number of loads that each crew can collect per day. To make this calculation, managers will need to estimate administrative and break time, hauling route and other travel time, and actual collection time. Table 4-10, item 3, presents methods for estimating these times.

Labor and equipment costs should be estimated for each collection system being considered. First, using the total quantity of waste that will be generated and number of loads that can be collected each day, collection managers should calculate the number of vehicles and crews that will be required to collect waste (see Table 4-10, item 4). Then, these numbers, along with equipment and cost information, can be used to calculate the annual cost of each collection alternative (see Table 4-10, item 5).

Analyzing Transfer Elements

For alternatives that include a transfer component, waste transfer costs should be analyzed and included as part of the overall system costs. Table 4-12 presents a list of capital and operating and maintenance costs for transfer systems.

Alternatives that include transfer systems should show reduced collection costs to offset some or all of the transfer costs. There are several ways to reduce collection costs; three examples are given below:

- Vehicle operating costs can be reduced if collection vehicles travel fewer miles to empty wastes.
- Nonproductive time during hauls and personnel costs can be reduced if crews spend more time on collection routes; this may also reduce the number of collection crews required.
- Vehicle maintenance costs from flat tires and damage to axles and other undercarriage parts can be reduced if vehicles deliver wastes to a transfer facility rather than directly to a landfill.

Selecting A Collection and Transfer Alternative

Decision makers must carefully consider many factors.

Appropriate public officials must eventually select a preferred system for implementation. Usually the authority for final approval rests with a body of elected officials, such as town board, city council, or county board. The type of solid waste collection services provided and their associated costs usually evoke considerable debate when establishing a new service or modifying an existing service. Issues that are usually important to elected officials in evaluating collection and transfer alternatives, and which staff should be prepared to address in their recommendations, include the following:

- costs of required new equipment and ability of community to obtain financing for it
- costs to operate collection system and transfer facilities

Table 4-11

Steps for Conducting a Time Study

1. Select crew(s) representative of average level and skill level.
2. Determine the best method (series of movements) for conducting the work.
3. Set up a data sheet that can be used to record the following information: date, name of crew members and time recorder, type of collection method and equipment (including loading mechanism), specific area of municipality, and distance between collection points.
4. Divide loading activity into elements that are appropriate for the type of collection service. For example, the following elements might be appropriate for a study of residential collection loading times:
   - time to travel from last loading point to next one
   - time to get out of vehicle and carry container to the loading area
   - time to load vehicle
   - time to return container to the collection point and return to the vehicle.
5. Using a stop watch, record the time required to complete each element for a representative number of repetitions. Time may be measured using one of the following two methods:
   - Snapback method: The time recorder records the time after each element and then resets watch to zero for measurement of the next element.
   - Continuous method: The time recorder records the time after each element but does not reset the watch so that it moves continuously until the last element is completed.

   Because the continuous method requires the time recorder to perform fewer movements and no time is lost for watch resetting, the continuous method is usually recommended.

   The number of repetitions that will be representative depends on the time required to complete the overall activity (cycle). The following numbers of repetitions have been suggested as sufficient :*

Number of Repetitions	Minutes Per Cycle	Number of Repetitions	Minutes Per Cycle
60	0.50	20	2.0
40	0.75	15	5.0
30	1.00	10	10.5

6. Determine the average time recorded (T_o) and adjust it for "normal" conditions.

   In the case of waste collection, adjustments should be made for delays and for crew fatigue. These adjustments are typically in terms of the percent of time spent in a workday. The delay allowance (D) should include time for traffic conditions, equipment failures and other uncontrollable delays. Crew fatigue allowance (F) should include adequate rest time for recovery from heavy lifting, extreme hot and cold weather conditions, and other circumstances encountered in waste collection. The allowance factors (D and F) along with the average observed time (T_o), can be used to estimate the "normal" time (T_n):

   $$T_n = (T_o) \times [1 + (F + D)/100]$$

   This "normal" time is the loading time required for the particular area, and collection system.

   For other activities, adjustments are also made for personal time (bathroom breaks). In this case, adjustment for personal time is made when calculating the number of loads/crew/day.

Sources: (1) Miller and Schmidt, 1984; *(2) These values only, from Presgrave, 1944

- compatibility of total costs with budget available for solid waste services
- differences in levels of service provided by alternative systems
- ability of system to meet public's demands or expectations for service
- proposed methods for financing system costs and public acceptability of those methods
- the system's effects on efforts to meet the community's waste reduction goals
- compatibility of proposed roles for public and private sectors with political support for them
- public's interest or disinterest in changing present arrangements for collecting solid waste and recyclables.

DEVELOPING COLLECTION ROUTES AND SCHEDULES

Efficient routing decreases program costs by reducing labor expended in collection.

Detailed route configurations and collection schedules should be developed for the selected collection system. Efficient routing and rerouting of solid waste collection vehicles can decrease costs by reducing the labor expended for collection. Routing procedures usually consist of two separate components: microrouting and macrorouting.

Macrorouting, also referred to as route balancing, consists of dividing the total collection area into routes sized so they represent one day's collection for one crew. The size of each route depends on the amount of waste collected per stop, distance between stops, loading time, and traffic conditions. Barriers, such as railroad embankments, rivers, and roads with heavy competing traffic, can be used to divide route territories. As much as possible, the size and shape of route areas should be balanced within the limits imposed by such barriers.

For large areas, macrorouting can be best accomplished by first dividing the total area into districts, each consisting of the complete area to be serviced by all crews on a given day. Then, each district can be divided into routes for individual crews.

Using the results of the macrorouting analysis, microrouting can define the specific path that each crew and collection vehicle will take each collection day. Results of microrouting analyses can then be used to readjust macrorouting decisions. Microrouting analyses should also include input and review by experienced collection drivers. Microrouting analyses and planning can do the following:

Table 4-12

Transfer System Costs

Capital Costs	Operating and Maintenance Costs
• Land	• Labor for station operation and vehicle hauling
• Buildings	• Utility service charges
• Utilities	• Station and vehicle maintenance
• Site development (on- and off-site)	• Insurance
• Material handling and processing equipment	• Taxes
• Transfer vehicles	• Vehicle license
• Design and permitting	• Facility permit
• Legal and financing fees	• Vehicle operation (tires, oil, fuel)
	• Host community benefits
	• Renewal and replacement
	• Reserve on contingencies

Source: W. Pferdehirt, University of Wisconsin–Madison Solid and Hazardous Waste

- increase the likelihood that all streets will be serviced equally and consistently
- help supervisors locate crews quickly because they know specific routes that will be taken
- provide theoretically optimal routes that can be tested against driver judgment and experience to provide the best actual routes.

Routes may need seasonal adjustments.

The method selected for microrouting must be simple enough to use for route rebalancing when system changes occur or to respond to seasonal variations in waste generation rates. For example, growth in parts of a community might necessitate overtime on several routes to complete them. Rebalancing can perhaps consolidate this need for increased service to a new route. Also, seasonal fluctuations in waste generation can be accommodated by providing fewer, larger routes during low-generation periods (typically winter) and increasing the number of routes during high-generation periods (typically spring and fall).

Heuristic Route Development: A Manual Approach

The heuristic route development process is a relatively simple manual (i.e., not computer-assisted) approach that applies specific routing patterns to block configurations. USEPA developed the method to promote efficient routing layout and to minimize the number of turns and dead space encountered (USEPA, 1974).

When using this approach, route planners can use tracing paper over a fairly large-scale block map. The map should show collection service garage locations, disposal or transfer sites, one-way streets, natural barriers, and areas of heavy traffic flow. Routes should then be traced onto the tracing paper using the rules presented in Table 4-13.

Table 4-13
Rules for Heuristic Routing

1. Routes should not be fragmented or overlapping. Each route should be compact, consisting of street segments clustered in the same geographical area.
2. Total collection plus hauling times should be reasonably constant for each route in the community (equalized workloads).
3. The collection route should be started as close to the garage or motor pool as possible, taking into account heavily traveled and one-way streets (see rules 4 and 5).
4. Heavily traveled streets should not be collected during rush hours.
5. In the case of one-way streets, it is best to start the route near the upper end of the street, working down it through the looping process.
6. Services on dead-end streets can be considered as services on the street segment that they intersect, since they can only be collected by passing down that street segment. To keep left turns at a minimum, collect the dead-end streets when they are to the right of the truck. They must be collected by walking down, backing down, or making a U-turn.
7. Waste on a steep hill should be collected, when practical, on both sides of the street while vehicle is moving downhill. This facilitates safety, ease, and speed of collection. It also lessens wear of vehicle and conserves gas and oil.
8. Higher elevations should be at the start of the route.
9. For collection from one side of the street at a time, it is generally best to route with many clockwise turns around blocks.

   Note: Heuristic rules 8 and 9 emphasize the development of a series of clockwise loops in order to minimize left turns, which generally are more difficult and time-consuming than right turns. Especially for right-hand-drive vehicles, right turns are safer.
10. For collection from both sides of the street at the same time, it is generally best to route with long, straight paths across the grid before looping clockwise.
11. For certain block configurations within the route, specific routing patterns should be applied.

Source: American Public Works Association, 1975

Computer-Assisted Routing

The use of computer-assisted routing is growing.

Computer programs can be helpful in route design, especially when routes are rebalanced on a periodic basis. Programs can be used to develop detailed microroutes or simpler rebalances of existing routes. To program detailed microroutes, planners require information similar to that needed for heuristic routing. This information might include block configurations, waste generation rates, distance between residences and between routes and disposal or transfer sites, topographical features, and loading times. Communities that already have a geographic information system (GIS) database are in an especially good position to take advantage of computerized route balancing.

Municipalities can also use computers to do simple route rebalancing. For example, the city of Wilmington, Delaware, used a spreadsheet program, average generation rates, and block configuration data to balance the weight of waste collected on each route. The city assumed that loading times were equal in all areas and altered the boundaries of existing routes. Specific collection vehicle paths were left to drivers. As a result of this simple rebalancing, the city was able to reduce its waste collection crew and save collection costs. For smaller communities, rebalancing can be accomplished using manual methods.

IMPLEMENTING THE COLLECTION AND TRANSFER SYSTEM

Implementing a collection and transfer system involves the following activities, which are described in more detail in the paragraphs below:

- finalizing and modifying the system management plan
- purchasing and managing collection and transfer equipment
- hiring and training personnel
- developing and managing contracts with labor unions and private collection companies
- providing public information
- constructing and operating transfer, administrative, and maintenance facilities.

Finalizing and Implementing the System Management Plan

The management plan should be concise, easy to follow, and well-organized.

Whether a municipality provides collection services or manages the efforts of a private or regional group, a clear organizational structure and management plan are needed. The management plan and structure should be reviewed periodically as implementation of collection services proceeds and continues.

The organizational structure should be simple, with a minimum of administrative and management layers between collection crews and top management. Structures should be clear, but kept sufficiently flexible to readily adapt to changing performance requirements. All workers in the department should clearly understand the department's mission and their own roles in achieving that mission. Through training, incentives, and reinforcement by management, workers should be encouraged to be customer-oriented and team contributors.

Details about system funding, accounting, billing, and performance monitoring should be developed and periodically reviewed. Feedback mechanisms to help crews review their performance and to help managers monitor the performance of crews, equipment, and the overall organization should be developed and used to achieve continuous improvement.

Purchasing and Managing Equipment

Equipment Purchasing

To purchase equipment most municipalities issue bid specifications, which are to be the basis of contractors' bids. Such specifications may either give detailed equipment requirements or be based on more general performance criteria. Detailed specifications include exact requirements for equipment sizes and capacities, power ratings, etc. Performance specifications often request that equipment be equivalent to certain available models, and meet standards for capacity, speed, maneuverability, etc.

Equipment Maintenance

A well-designed preventive maintenance program

- *keeps repair costs down*
- *makes vehicles more reliable.*

Municipalities may either perform equipment maintenance themselves, contract with a local garage, or in some cases, contract with the vehicle vendor at the time of purchase. Usually, municipal collection agencies elect to maintain vehicles using municipal facilities.

When equipment is maintained by the municipality, maintenance facilities may be under the authority of either a central municipal service or a specialized maintenance service for waste collection vehicles only. There is no consensus as to which form of organization is more effective. The advantages of a single-department maintenance service are that the maintenance facility is likely to be located closer to the garage or disposal facilities operated by the collection department, the maintenance personnel will usually be more responsive to the needs of collection department staff and vehicles, and the mechanics are likely to be better acquainted with the needs of the collection fleet's vehicles.

Centralization of all fleet services may allow a municipality to realize some cost savings by minimizing duplication of some costs for labor, buildings, equipment, and spare parts. Often smaller communities have combined municipal fleet services, and larger cities have multiple, specialized fleet services.

Regardless of the organizational location of the maintenance facility, its efficiency can be increased by developing a well-defined organizational structure and good reporting procedures. In many vehicle maintenance organizations it is most efficient to have a diagnostician and mechanics who specialize in certain areas such as routine maintenance, compaction equipment repair, etc.

A well-designed preventive maintenance program is essential to controlling repair costs and sustaining high reliability for fleet vehicles. Without an effective preventive maintenance program, vehicles are more likely to experience on-route breakdowns, which are particularly expensive because of towing costs, lost labor, and overtime. As part of the preventive maintenance program, the collection crew should check the vehicle chassis, tires, and body daily, and report any problems to maintenance managers. In addition, each vehicle should have an individual maintenance record that includes the following items:

- a preventive maintenance schedule
- a current list of specific engine or packer problems
- for each maintenance event, a description of repairs and a list including repair date, mechanic, cost, type and manufacturer of repair parts, and the length of time the truck was out of service.

Management personnel should periodically review this information to refine maintenance plans for individual vehicles and to identify improvements to the overall maintenance program.

Equipment Replacement

Plan for equipment replacement.

Some municipalities or hauling companies replace their trucks at a pre-specified mileage or time interval. Although this rule-of-thumb approach is easy to administer, it often results in "lemons" being kept longer than they should and some good trucks being replaced earlier than economically justifiable.

A truck replacement strategy that is based on the actual costs of owning and maintaining individual trucks is likely to result in a more effective use of resources. Using this approach, costs are tracked for each truck, and each truck is replaced as the costs of continuing to own that particular truck exceed the costs of purchasing and operating a replacement truck. Annual costs that should be tracked for existing trucks include the following:

- parts and labor for repair and maintenance
- costs for towing and lost crew time due to breakdowns
- capital loss based on actual decrease in resale value (not book depreciation)
- vehicle operating costs (fuel, insurance, tires, etc.).

Recorded costs should be compared with estimated costs for new trucks, and individual trucks replaced as their individual maintenance records warrant. Replacements of all trucks may nevertheless be required when changes to the entire fleet are needed to accommodate changes to collection procedures. Collection trucks retired from active service can either be used as standby vehicles, for replacement parts, or deployed for other types of service (for example, using old compactor trucks to collect yard materials).

Hiring and Training Personnel

As in all organizations, good personnel management is essential to an efficient, high-quality waste collection system. Management should therefore strive to hire and keep well-qualified personnel for solid waste management.

To hire qualified people, many municipalities use a civil service system. If a civil service system is not used, municipalities should develop a system that minimizes political favoritism in the hiring process. The recruitment program should assess applicants' abilities to perform the types of physical labor required for the collection equipment and methods used. To retain employees, management should provide a safe working environment that emphasizes career advancement, participatory problem solving, and worker incentives.

Safety

Concern for safety is crucial, and an ongoing safety program is a must.

Safety is especially important because waste collection employees encounter many hazards during each workday. As a result of poor safety records, insurance costs for many collection services are high. Collection personnel frequently encounter the following hazards:

- busy roads and heavy traffic
- rough- and sharp-edged containers that can cause cuts and infections
- exposure to injury from powerful loading machinery
- heavy containers that can cause back injuries
- dangers from discarded household hazardous wastes such as herbicides, pesticides, solvents, fuels, batteries, and swimming pool chemicals.

To minimize injuries, haulers should have an ongoing safety program. This program should outline safety procedures and ensure that all personnel are properly trained on safety issues. The safety program should include, at a minimum, the following items:

An adequate safety program includes

- *training*
- *record keeping*
- *protective clothing*
- *refresher sessions.*

- procedures and training in proper lifting methods, material handling, equipment operation, and safe driving practices
- a reporting and record-keeping procedure for accidents
- requirements for protective clothing such as hard hats, gloves, goggles, safety shoes, high-visibility vests, etc.
- frequent refresher sessions to remind workers of safe working habits and department requirements.

Collection managers should closely monitor worker accident and injury reports to try to identify conditions that warrant corrective or preventive measures. For example, some municipalities now offer their collection staff the use of lifting belts to help prevent lower-back injuries. Similarly, during hot weather some municipalities offer workers free beverages that replace electrolytes. The cost of an aggressive, preventive safety program is almost certain to be offset by savings from lost work time and injuries.

Comfort

Concern for employee comfort and providing worker incentives encourage safer work.

Appropriate work place comfort reduces the potential for injuries and enhances employee morale. To make working conditions comfortable, haulers should provide adequate equipment, clothing, and rest facilities. Many haulers furnish clean, comfortable uniforms for employees; doing so, they note, benefits employees and improves the public image of the hauler. In addition, many haulers furnish rain gear, boots, and other special clothing for inclement weather.

Haulers should also provide adequate facilities to meet employees' needs. These facilities should include nearby space for rest rooms, showers, lockers and lunchrooms.

Training

Haulers should develop an employee training program that helps employees improve and broaden the range of their job-related skills. Such training underscores the importance of each individual's contribution to the hauler's overall performance and helps foster a sense of professionalism. The haulers benefit from improved performance and increased flexibility in assigning work to staff.

Training opportunities should also be developed to address safety and liability concerns. Education should address such subjects as driving skills, first aid, safe lifting methods, identification of household hazardous wastes, avoidance of substance abuse, and stress management.

Worker Incentives

Incentives should be developed to recognize and reward outstanding performance by employees. Ways to accomplish motivation include merit-based compensation, awards programs, and a work structure that emphasizes task completion rather than "putting in your time."

Compensation should provide managers with flexibility to reward good performance. Feedback on employee performance should be regular and frequent, however, and not just at annual evaluation time. Award programs acknowledge an employee's accomplishments in the presence of his or her peers. Such programs can be internal (e.g., "employee of the month" award) or through professional organizations such as the Solid Waste Association of North America (SWANA) and the National Solid Waste Management Association (NSWMA).

To improve the efficiency of collection crews, many municipalities use a task system. Under this approach, crew members may go home after their daily collection responsibilities have been completed, rather than wait around until a specified quitting time. This approach provides a built-in motivation for crews to work efficiently and usually reduces the amount of overtime required.

Task system design must ensure a high quality of service; it must also ensure that crews do not compromise safety to complete their work. Routes should be carefully drawn up so that each represents a balanced and reasonable workday. Also, crews should be trained to work at a pace that discourages poor-quality service and minimizes safety hazards or injuries. However, if a task system is used, it is important to ensure that crews do not sacrifice safety or customer satisfaction in the interest of finishing early.

Customer complaints should be handled by crew supervisors, and crews should address the problems raised.

To encourage high-quality service, crew supervisors should field customer complaints and then have the crew receiving the complaint address problems associated with it. In some cities, a separate crew addresses complaints, but this system requires other feedback mechanisms to help crews learn from their mistakes.

Developing and Managing Contracts with Labor Unions and Private Collectors

Labor unions are common in much of the solid waste collection industry. It is therefore likely that municipal collection departments will be required to bargain collectively with labor unions. If this is the case, the department should usually designate a labor management relations group to handle collective bargaining. In addition, as part of the labor management relations process, the department should set a formal procedure for managing employee grievances. This procedure should be designed to allow employees to file grievances without concern of reprisal. Grievances should be handled quickly and fairly.

If a municipality decides to contract for collection services, selection of the contractor will usually require the issuance of service specifications and evaluation of contractors' bids. The municipal department responsible for overseeing collection should work with municipal purchasing groups to request, evaluate, and award bids for waste collection. The municipality should ensure that it has adequate resources to monitor the performance of collection contractors in meeting contract requirements.

Providing Public Information

Maintaining good communications with the public is important to a well-run collection system. Residents can greatly affect the performance of the collection system by cooperating with set-out and separation requirements, and by keeping undesirable materials, such as used oil, from entering the collected waste stream.

System managers must maintain effective communication with the public at every stage of the process.

Collection system managers should creatively use available communication methods and materials to remind customers of set-out requirements, inform them of changes to those requirements, provide them with names and telephone numbers of key contacts, and provide them with helpful feedback on system performance. Commonly used methods of communicating information include brochures, articles in community newsletters, newspaper articles, announcements and advertisements on radio and television, informational attachments to utility bills, and school handouts. These materials should be designed to communicate new information, but also to remind customers of service requirements; this is particularly important in communities with highly transient populations such as university students.

Communication materials should be used to help residents understand community solid waste management challenges and the community's progress in meeting them. For example, residents should be regularly updated on how well the community's recycling program is doing in meeting waste reduction goals and any recurring problems, such as contamination of materials set out for collection. Residents should also be kept informed about issues such as the availability and costs of landfill capacity so that they develop an understanding of the issues and a desire to help meet their community's solid waste management needs.

In San Diego, collection workers go door-to-door to explain new programs. This approach gives crews an opportunity to meet their customers and develop greater personal awareness and pride in meeting their customers' needs.

MONITORING SYSTEM COSTS AND PERFORMANCE

System costs and performance in light of program goals should be continually monitored.

Short-term feedback is necessary for accurate program evaluation and planning to meet new needs.

Collection and transfer facilities should develop and maintain an effective system for cost and performance reporting. Each collection crew should complete a daily report that includes the following information:

- total quantity hauled (tons or cubic yards)
- total distance and travel times to and from the disposal site
- amounts delivered to each disposal, transfer, or processing facility (if there is more than one site)
- waiting times at sites
- number of loads hauled
- vehicle or operational problems needing attention.

In addition, transfer stations should collect vehicle and weight information. If a scale is used at the transfer station, waste quantities, vehicle origins, and delivery times can be collected using a computerized logging system.

Collected data should be used to forecast workloads, track costs, identify changes in the generation of wastes and recyclables, trace the origin of problematic waste materials, and evaluate crew performance. Managers should use such information to identify changes in service needs and to evaluate the effectiveness of the collection system in meeting its goals and objectives. To be effectively used by managers for such purposes, reports must provide concise summaries that track the status of identified key performance parameters, while allowing optional access to more detailed data that can be used to more thoroughly investigate a particular problem or issue.

Just as the goals of a collection program set its overall directions, a monitoring system provides the short-term feedback necessary to identify the course corrections needed to achieve those goals.

REFERENCES

American Public Works Association, Institute for Solid Wastes. 1975. *Solid Waste Collection Practice*, 4th edition. Chicago, IL: APWA.

Hickman, H. L. 1986. "Collection of Residential Solid Waste." In *The Solid Waste Handbook: A Practical Guide*, ed. by W. D. Robinson. NY: John Wiley & Sons.

Lueck, G.W. 1990. "Elementary Lessons in Garbage Appreciation," *Waste Age* (September).

Peluso, R. A. and E. H. Ruckert, III. 1989. "Designing for Smooth Transfer Operations." *Waste Age*, April.

Presgrave, R. 1944. *The Dynamics of Time Study*. Toronto: Univ. of Toronto Press.

Schaper, L. T. 1986. "Transfer of Municipal Solid Waste." *The Solid Waste Handbook.* NY: John Wiley & Sons.

Tchobanoglous, G.; H. Theisen; and R. Eliassen. 1977. *Solid Wastes: Engineering Principles and Management Issues*. NY: McGraw-Hill.

USEPA. 1974. *Heuristic Routing for Solid Waste Collection Vehicles*. DSW / SW-1123.

USEPA. 1974a. *Residential Collection Systems, Volume 1: Report Summary*. SW-97c.1.

5 SOURCE REDUCTION

According to estimates made by the Congressional Office of Technology Assessment (OTA), the appropriate technology and adequate economic conditions already exist to reduce solid waste generation by 50 percent in the next few years. This chapter describes options for establishing source reduction programs in the government, commercial and public sectors, and for householders. It illustrates, by example, how to measure the success of such programs. It also lists references and sources that can provide decision makers with more details about designing and implementing specific source reduction programs.

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5 HIGHLIGHTS

Source reduction implies reducing waste at its original source.
(p. 5-5)

In this chapter source reduction implies reducing the volume or toxicity of waste at the source by changing the material-generating process; it includes incorporating reduction in the design, manufacture, sale, purchase, and use of products and packaging. Other terms are often used to mean source reduction, including waste reduction, waste prevention, waste minimization, pollution prevention, and precycling.

Source reduction includes several strategies.
(p. 5-6)

Source reduction reduces the amount of materials we produce and the harmful environmental effects associated with producing and disposing of them. It includes:

- reduced material use in product manufacture
- increased useful life of a product through durability and repairability
- decreased toxicity
- material reuse
- reduced/more efficient consumer use of materials
- increased production efficiency resulting in less production waste.

Source reduction offers several opportunities for cost savings.
(p. 5-7)

- direct savings
- avoided waste collection, transportation, and disposal costs
- decreased pollution control, liability, and regulatory compliance costs
- reduced product and material use and disposal costs

Source reduction legislation often focuses on establishing the following:
(p. 5-7 — 5-9)

- specific goals
- government procurement and purchasing requirements
- packaging requirements and guidelines
- labeling guidelines
- business planning and reporting requirements
- banning yard trimmings from disposal
- banning specific chemicals and types of packaging

Both economic incentives and disincentives can be used to encourage source reduction.
(p. 5-9 — 5-10)

Economic *incentives* include the following:

- funding research and development of source reduction and education programs, developing source reduction measurement standards, and improved product designs
- funding waste exchanges
- funding other materials reuse programs and businesses
- subsidizing repair businesses
- providing tax credits or exemptions to industries that meet set goals or design criteria.

Economic *disincentives* include the following:

- creating taxes that reflect disposal costs of packaging
- placing taxes on use of virgin materials when recycled materials would work
- taxing disposal products
- instituting volume-based rates for waste collection programs.

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Waste audits are a key to establishing source reduction programs.
(p. 5-10 — 5-11)

Waste audits are the key to establishing a successful source reduction program. They involve assessing the material flow through an institution and preparing accounting for the amount of materials purchased, used, recycled, and disposed of. A waste audit includes the following steps:

- describing current purchases, use and disposal requirements and methods
- identifying amounts and types of materials generated, including those to target for source reduction
- estimating cost savings
- implementing and monitoring the program.

Selective purchasing is another strategy for source reduction.
(p. 5-11 — 5-12)

Organizations, institutions, and individuals can preferentially purchase products that are durable, reusable, and repairable; buy in bulk; and avoid purchasing single-use products. They can also consider a product's solid waste and toxicity production, recycled content, packaging, resource use, and ultimate disposal. Shifting purchasing priorities toward source reduction might entail rewriting purchasing codes and reviewing and updating material classifications based on new product developments. It is important for solid waste, environmental, and purchasing officials at all levels of government to work together in planning, implementing, and monitoring source reduction programs.

Source reduction programs for businesses and other institutions may include several elements.
(p. 5-13 — 5-14)

- support and policy directives from management
- a waste reduction team or coordinator
- accounting of materials purchased and waste produced
- reduction plan targeting materials and production practices
- employee education
- feedback and reevaluation
- produce or sell products designed to be reusable and more durable

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Source reduction strategies for industries include the following:
(p. 5-14 — 5-15)

- manufacturing redesign
- product redesign
- designing products with durability, reuse, and ease of repair in mind
- initiating "in-house" source reduction programs at company facilities

5 HIGHLIGHTS (continued)

Businesses and other institutions can also implement a number of source reduction strategies.

(p. 5-15 — 5-16)

- Copy double sided.
- Use electronic mail.
- Circulate only one copy of printed material (memos, documents); use routing slips indicating who should read it and who has already seen it.
- Establish central document and file areas.
- Reuse paper that has been printed on only one side.
- Reuse and return corrugated boxes.
- Purchase cooperatively; order supplies in bulk with other businesses or institutions (for example, cleaning products).
- Establish a waste exchange with other nearby businesses (for example, merchants sharing a mall).
- Sell items in reusable containers.
- Provide items in bulk and encourage shoppers to buy in bulk.
- Provide shoppers with incentives to reuse store packaging.

A focus on packaging is another source reduction strategy.

(p. 5-16)

Packaging should protect products from chemical and physical damage. Once this goal is achieved, source reduction decision-making guidelines for packaging professionals should be followed to evaluate each type of package design. Source reduction considerations should be incorporated into all packaging to the extent possible. To assess packaging, the following should be considered.

- Evaluate the need for any package at all.
- Decide if any of the package components can be eliminated.
- Assess the use of toxic chemicals and replace them with less harmful chemicals using the smallest amount possible.
- Design a package that is reusable.
- Find ways to reduce the package size or use of materials.

Source reduction programs aimed at consumers and residents can achieve significant benefits.

(p. 5-18 — 5-22)

An aggressive source reduction campaign for the residential/consumer sector involves using a variety of approaches, in addition to regulatory tools. Decision makers can consider using the following:

- economic incentives, such as unit-based garbage fees
- education, technical assistance, and promotions aimed at increasing participation in source reduction activities like yard material reduction programs and precycling
- investment in source reduction tools such as materials exchange databases or providing backyard composting bins
- regulations and legislation.

5 SOURCE REDUCTION

UNDERSTANDING AND FOSTERING SOURCE REDUCTION

Defining Source Reduction

The USEPA considers source reduction the highest priority method for addressing solid waste issues.

In its *Agenda for Action* (1989), the U.S. Environmental Protection Agency gave source reduction the highest priority as a method for addressing solid waste issues. Because it minimizes the creation of materials and toxics, source reduction is the only practice that is preventative. This proactive approach also reduces material and energy use. Recycling, composting, waste-to-energy, and landfilling are reactive methods for recovering and managing materials after they are produced.

The USEPA defines source reduction as the design, manufacture, purchase or use of materials to reduce their quantity or toxicity before they reach the waste stream. The National Recycling Coalition (NRC) adopted a somewhat different definition in its “Measurement Standards and Reporting Guidelines.” They define source reduction as “any action that avoids the creation of waste by reducing waste at the source, including redesigning of products or packaging so that less material is used; making voluntary or imposed behavioral changes in the use of materials; or increasing durability or re-usability of materials.” NRC adds that source reduction “…implies actions intended to encourage conservation of materials.” Others have added to the definition the caution that source reduction should not increase the net amount or toxicity of wastes generated throughout the life of a product. Although national policy denotes that it is the highest priority waste management technique, currently there is no universally accepted definition of source reduction.

Source reduction implies reducing waste at the source by changing the material-generating process, and also includes incorporating reduction in the design, manufacture, sale, purchase, and use of products and packaging.

Several terms are often used to mean source reduction. These include waste reduction, waste prevention, waste minimization, pollution prevention, and precycling. The precise meanings may depend on the context in which the terms are used. USEPA often uses the term “waste prevention” in lieu of source reduction. Source reduction as used in this chapter implies reducing waste at the source by changing the material-generating process, and also includes incorporating reduction in the design, manufacture, sale, purchase, and use of products and packaging. Source reduction programs can be targeted to reach consumers (often known as “precycling”) as well as manufacturers. Waste reduction is a broader term encompassing all waste management methods, i.e., source reduction, recycling, and composting, that result in reduction of waste going to the combustion facility or landfill. Waste minimization refers to activities specifically designed to reduce industrial hazardous and toxic wastes as they affect land disposal as well as contribute to air and water pollution. Pollution prevention includes input optimization, the reduction of nonproduct outputs, and production of low-impact products. Precycling refers to the decision-making process that consumers use to judge a purchase based on its waste implications; criteria used in the process include whether a product is reusable, durable, and repairable; made from renewable or nonrenewable resources; over-packaged; or in a reusable container.

Source Reduction as a First-Choice Approach

Source reduction reduces the amount of materials produced and the harmful environmental effects associated with producing and disposing of them.

Promoting source reduction is important because it conserves resources, reduces disposal costs and pollution, and teaches conservation and prevention. It should, therefore, be given first consideration. Focusing only on recycling might promote the impression that recycling will take care of our waste problems. Source reduction and recycling, while important to distinguish from each other, can be promoted simultaneously. Source reduction is becoming recognized as a key component of integrated waste management. While its implementation is in its infancy, creative source reduction strategies are being developed and applied across the nation.

Source reduction is a practical approach to reducing the amount of materials we produce and the harmful environmental effects associated with producing and disposing of them. The basic elements of source reduction include the following:

- reduced material use in product manufacture
- increased useful life of a product through durability and repairability
- decreased toxicity
- material reuse
- reduced / more efficient consumer use of materials
- increased production efficiency resulting in less production waste.

Tradeoffs between source reduction, durability, recyclability, use of recycled material, and other environmental benefits can occur. If known, these should be noted and analyzed. The process resulting in the greatest overall environmental benefit should be chosen.

Life cycle analysis details all resources used and the products and by-products generated throughout a product's entire life.

Ideally, to assess and quantify these tradeoffs, a life cycle analysis would be performed. Life cycle analysis is a detailed look at all resources used and the products and by-products generated throughout the entire life of a product or process. The cradle-to-grave analysis (1) starts with raw materials and energy acquisition, (2) then examines manufacturing and product fabrication; filling, packaging, and distribution; and consumer use and reuse; and (3) ends with analysis of waste management. Currently, life cycle analysis procedures are being developed to assess the overall environmental impact of products and their packages. Until there are standardized methods for performing a life cycle analysis, results from such studies may not be comparable or reliable. USEPA is working on guidelines for a more consistent approach to life cycle analysis. Even when the guidelines are complete, however, conducting a life cycle analysis will still be too complex and expensive for most local solid waste managers.

Measuring Source Reduction

Monitoring should be an integral part of source reduction programs. Although standardized methods to measure source reduction have yet to be developed, tracking the costs associated with source reduction and integrating them into the decision-making process is essential to developing accountability. Monitoring also facilitates evaluating programs for efficiency and identifying possible source reduction measures and program revisions. Tracking the effectiveness of source reduction initiatives is also important for obtaining funding and resources for these programs.

Source reduction is more difficult to measure on a broad scale than other methods of solid waste management. It is difficult to measure what hasn't been produced, and to discern which reductions are due to prevention and which are due to other factors such as the economy, business cycles, or seasonal changes. When several waste reduction techniques are used simultaneously, it is not easy to determine which portion of the diversion was due to source reduction, for example, separating it from recycling or composting. However, on a company-by-company and product-by-product basis, measurements such as the savings achieved by substituting one product with another are obtainable.

Quantifying source reduction program results is in the early stages of development.

Quantifying program results through accepted measurement techniques is in the early stages for most types of waste reduction practices and to a greater extent, for source reduction. A small amount of source reduction data has been collected, but without established measurement tools, the accuracy of some reports is questionable. This chapter presents examples of programs that have measured source reduction success.

Source reduction often results in substantial and measurable cost savings. These include avoided collection, transportation, and disposal costs, and direct savings. In addition, source reduction is cost efficient in decreasing pollution control, purchase, use, and regulatory compliance costs. It also reduces product and material use and disposal costs in the manufacturing process, making business operations more efficient overall. There is some concern that source reduction might reduce economic growth by decreasing consumption. However, source reduction offers opportunities for economic gain. Many businesses are becoming more competitive through source reduction practices and others are finding that products designed for source reduction achieve significant sales.

The technology and economics exist for industry to reduce solid waste by 50 percent.

According to Congressional Office of Technology Assessment (OTA) estimates, the technology and economics exist for industry to reduce solid waste by 50 per cent within the next few years. This chapter describes options for establishing source reduction programs in the government, commercial, and public sectors, and illustrates, by example, how to measure their success. It also provides references which can provide decision makers with more details about designing and implementing specific source reduction programs.

SOURCE REDUCTION POLICY

Regulation

Legislation and regulation governing source reduction programs are increasing. Source reduction legislation often focuses on establishing the following:

Legislation and regulation governing source reduction programs are increasing.

- specific goals
- government procurement and purchasing requirements
- packaging requirements and guidelines
- labeling requirements and guidelines
- business planning and reporting requirements
- yard material bans
- specific chemical and packaging bans.

Education, including promotion, technical assistance, planning and reporting, and economic incentives are key elements of such legislation. To achieve a comprehensive policy approach, decision makers can focus on four strategies:

- “command and control” regulations
- economic incentives and disincentives
- education and technical assistance
- government financial support for source reduction practices (i.e., supplying bins for home composting of yard trimmings).

States may require local governments to institute specific source reduction practices.

Local governments might be required by state laws to institute specific source reduction practices. In many cases, decision makers can model local policy after state directives to promote source reduction in their own institutions and in commercial and residential sectors.

Some states, including Connecticut, Pennsylvania, Maine, New Jersey, New York, Massachusetts, and Michigan, have set source reduction goals that specify the percent of reduction to be achieved in designated years. To be most effective, the goals also include a baseline year to measure from and measurement procedures. Establishing source reduction goals can be important in ensuring that source reduction programs are established and funding and staff are allocated.

Wisconsin and Connecticut statutes direct state agencies to modify purchasing to discourage buying single-use, disposable products and encourage purchasing multiple-use, durable products. Connecticut's model establishes specific goals and deadlines for achieving reduction. Local governments can apply such policies as well.

Acts in Minnesota and Wisconsin target the elimination of excess packaging. New packaging can be reviewed to assess its potential impact on solid waste disposal and the availability of markets for recycling it. If it is determined to be "problem" packaging, it can be banned from sale in the state.

The Coalition of North East Governors (CONEG), which includes nine northeastern states, formed a Source Reduction Task Force in 1988. To achieve source reduction, they recommended voluntary source reduction by industry, establishment of consistent goals and standards, coordinated education, and incentives and disincentives. In addition, a Northeast Source Reduction Council was formed comprising members from government, industry and nonprofit groups. The council developed a set of "Preferred Packaging Guidelines." The guidelines recommend a hierarchy of packaging practices: no packaging; minimal packaging; consumable, returnable, or refillable (refill at least five times) reusable packaging; and recyclable packaging or recycled material in packaging.

Well-conceived labeling requirements and guidelines for products and packaging may help prevent waste.

Labeling requirements and guidelines for products and packaging can help prevent waste if they encourage consumers to choose products that generate less waste and if they encourage labels that are specific and accurate. In 1992, the Federal Trade Commission adopted guidelines for the use of labels which give examples of deceptive and non-deceptive claims, including source reduction claims. Some states, such as California, New York and Rhode Island, have established requirements for specific labels such as those for products with recycled content.

Legislation can also include limits on toxic content of products, review of new and existing products for undesirable components and characteristics, conditional bans on product sale or use based upon design criteria, and requirements for manufacturers to submit source reduction plans.

Some municipalities have also adopted source reduction legislation. They have set goals and banned certain packaging and disposable products from sale. Seattle, Washington has set a 1.9 percent source reduction goal and a 0.6 percent backyard composting goal.

Rhode Island requires businesses to submit detailed source reduction (and recycling) plans to the state. This was phased in for larger (500 or more employees) to smaller businesses (100 plus employees) between 1989 and 1990 and for small (less than 50 employees) businesses in 1991. They must conduct a waste audit and submit a detailed analysis, submit proposals for effective reduction and recycling, and prepare an annual report quantifying results. Businesses have 60 days to activate the plan before inspection by the state. Businesses totaling one third of Rhode Island's work force have submitted plans and have already realized large savings in avoided disposal costs.

The source reduction techniques used most frequently by 274 Rhode Island companies include double-sided copying (52 percent), reuse of shipping materials (31 percent), reuse of assorted materials (28 percent), and asking suppliers to reduce packaging (26 percent).

The Rhode Island study also found that materials exchanges were underused but that there is great potential for their use. A majority (63 percent) of businesses were interested in using this tool, with wood pallets and plastics the most likely possibilities for feasible exchanges.

New York City is considering requiring businesses of targeted sizes to perform and submit waste audits and to meet reduction goals according to a specific timetable.

Fourteen states ban yard trimmings from landfills.

Yard material, excluding grass left on the lawn and backyard compost materials, constitutes a significant portion of the waste stream: it comprised 18 percent of the 180 million tons of municipal solid waste generated in the United States in 1990. Fourteen states have adopted legislation banning yard material from landfills. Some programs include bans on leaves only, while others include garden debris and grass.

Banning items such as excess packaging is another source reduction tool. A Minneapolis / St. Paul ordinance bans any packaging that does not meet the test of "environmentally acceptable," which is defined as (1) reusable at least five times, (2) biodegradable (except plastic), or (3) recyclable in the city's recycling program.

Decision makers considering bans should be aware of their controversial nature and anticipate possible legal ramifications.

Packaging bans, however, are not source reduction legislation unless they encourage reusable packaging or packaging with lesser amounts of materials. Replacing disposable packaging with recyclable or compostable packaging would not qualify as source reduction unless the new package created less waste at the source. Decision makers considering bans should be aware of the difficulties associated with this controversial tool and should thoroughly research the legal ramifications before imposing a ban. Problems with interstate, regional, or local commerce laws might arise.

Economic Incentives and Disincentives

There are many ways that state and local governments can promote source reduction. Governments can fund research and development of source reduction programs, education programs, measurement standards, and product design. Funding materials exchanges is another method. The Minnesota Public Interest Research Group (MPIRG) operates the BARTER program, an information exchange for reuse of shipping and packing materials for small businesses. The New York City departments of Sanitation and Cultural Affairs together operate a reuse program, "Materials for the Arts," which matches business donations with the needs of nonprofit arts organizations. They pick up tax-deductible contributions of goods and equipment from businesses and individuals and take them to a warehouse for free pick-up by nonprofit organizations.

There are many ways that state and local governments can promote source reduction.

Subsidies for repair businesses or reuse organizations can be provided. Also, repair training programs at technical colleges can be supported. Local governments can sponsor programs or create opportunities for volunteer programs such as neighborhood repair centers or neighborhood tool banks. Governments can also provide incentives to manufacturers in the form of materials tax credits. Tax credits or exemptions can be given to industries that meet set goals or design criteria.

Taxes that reflect the disposal costs of packaging material can be applied at the manufacturing or the consumer levels. These are financial disincentives. At the manufacturing level, a tax can be placed on products with excessive packaging. A tax on each package produced regardless of its contribution to the waste stream is another method used. Such taxes are used in Florida and can be costly and cumbersome to administer in the initial years.

Taxes also can be placed on single-use products. The advantages of such taxes are that they include at least some of the true cost to society of the product and its package and, like the variable container rate on refuse, are fair in charging the generators responsible for producing the waste. The CONEG Task Force recommended adoption of a per-container charge system to encourage consumers to purchase less packaging.

More than 2,000 communities have unit-based garbage rates, which encourage manufacturers and consumers to reduce, reuse, and refill.

Wisconsin mandates unit-based rates or user-fee collection programs for all municipalities and counties that do not achieve a 25 percent landfill diversion rate. In addition to the inherent economic incentive to reduce waste in a unit-based system, Wisconsin offers additional grant monies to communities that implement the fee system. Although the legislation doesn't go into effect until 1995, more than 200 communities had instituted rate-based rates at the local level by 1993.

Minnesota required by January 1993 that all municipalities make the prorated share of garbage collection and disposal costs for each generator visible and obvious to the operator. Licenses must require that charges increase with the volume or weight of waste collected after a base unit size of service is provided.

More than 2,000 communities have instituted unit-based garbage rates. This kind of rate system provides manufacturers and consumers with an economic incentive to reduce, reuse, and refill.

Mandating minimum lengths for service warranties is another policy tool. This encourages the development and production of longer-lasting products.

GOVERNMENT SOURCE REDUCTION

Local government leaders can implement source reduction programs at three levels in their communities: (1) at the institutional level—local government offices and other facilities, such as schools, parks, city works garages, libraries, etc., (2) at the business / industry level, and (3) at the residential level. By implementing source reduction programs in their own offices and facilities, local governments not only reduce their own waste but also show their commitment to such programs. They can use their own source reduction experiences to illustrate the benefits of source reduction when developing similar programs in the commercial and residential sectors of their communities.

Facility Source Reduction Programs: Performing Waste Audits

Guidelines for establishing source reduction programs in local government institutions are similar to those for establishing commercial source reduction programs. This section describes the components of a successful program at the institutional level.

The key to establishing a successful source reduction program is the waste audit or assessment. Local government managers can perform a waste audit by following the methods detailed below. Some cities have staff who perform waste audits for local businesses or for government facilities.

Waste audits or assessments are the keys to successful source reduction programs.

A waste audit is an assessment of material flow through an institution. It is a detailed accounting of the amount of materials purchased, used, recycled, and disposed of. Because a waste audit forces a scrutiny of the path each material takes through a facility, it clarifies an otherwise complicated morass of materials that can differ from department to department within a facility. Audits help identify the points at which changes in purchasing, consumption, and use can reduce or eliminate material.

A waste audit includes the following steps: quantifying current disposal costs and discarded material; identifying and quantifying materials that are unnecessary, reusable and recyclable; estimating cost savings; and implementing and monitoring the program.

Waste audits include the steps described here.

- **Describe current disposal:** Examine size of refuse containers, percent filled, volume contained, density, frequency of collection and costs of collection. Published generation rates by type of facility such as restaurant, office, and schools, are available from industry and government documents. These provide estimated pounds generated per person per month. Multiply the rates by number of employees or residents.

- **Identify materials to target for source reduction:** Determine material composition in a facility by listing each type of material that enters it and all materials and waste it generates, such as paper, aluminum cans, metal shavings, plastic bags, corrugated boxes, and chemicals. List where they are stored or used (facility-wide or in a particular department) and estimate the amount of each recycled or discarded per month. Note the availability of alternatives or ability to reduce or reuse items in the facility.
- **Estimate cost savings:** Include avoided disposal costs, avoided material purchase costs, avoided replacement costs, and costs of reused alternatives and revenues from marketing scrap. Determine costs of backhauling, transportation for refilling, etc., and processing equipment, if the costs apply.
- **Implement and monitor the program:** Choose which measures to implement, keep records of material purchased, scrapped, reused, backhauled, and disposed of. Measure savings over the long term; estimated savings will not be realized immediately. Refine and adjust the program.

Work sheets can help guide waste audits and are available from many local and state government agencies.

Work sheets to assist in performing an audit are available as part of commercial recycling handbooks produced by many local and state government agencies. Some of these include Rhode Island, (OSCAR), 1988, "Handbook for Reduction and Recycling of Commercial Solid Waste"; The Alaska Health Project, 1988, *Profiting from Waste Reduction in Your Small Business: A Guide to Help You Identify, Implement, and Evaluate an Industrial Waste Reduction Program*; Mecklenburg County, North Carolina, 1988, *Possibilities and Practicalities of Business Waste Recycling*; and Seattle, Washington, 1989, *Commercial Waste Reduction Audit Manual.*

USEPA publications are also available as resources to help businesses. For example, the *Business Guide for Reducing Solid Waste* (EPA/530-K-92-004) offers step-by-step instructions designed to assist medium and large businesses, governments and other organizations establish waste reduction programs. It also includes work sheets. This publications and others are available free from the USEPA RCRA/Superfund Hotline: 800/424-9346.

Purchasing

Government procurement policies that make source reduction a priority can achieve a significant impact on the waste stream. Collectively, government represents approximately twenty percent of the gross national product (GNP) of the United States. As a result, the purchasing power of government can influence manufacturing practices towards implementing source reduction goals. Also, by implementing source reduction practices, government sets an example for business, industry and the public.

Government procurement policies emphasizing source reduction can significantly impact the waste stream.

As is done in consumer source reduction programs, state and municipal governments can preferentially purchase products that are durable, reusable, and repairable; buy in bulk; and avoid purchasing single-use disposable products. Also, governments can consider a product's solid waste and toxicity production, packaging, resource use, and ultimate disposal. Shifting purchasing priorities toward source reduction might entail rewriting purchasing codes and reviewing and updating material classifications based on new product developments. It is important for solid waste, environmental and purchasing officials at all levels of government to work together in source reduction program planning, implementation and monitoring.

When government personnel evaluate proposals for equipment and furniture purchases, they can include source reduction criteria in the decision-making process. Those products that offer extended warranties can receive extra points based on the number of years covered beyond the industry standard. ASTM standards for quality and durability of products can also be used. In a request for proposal (RFP), a guaranteed buy back for equipment and furniture can be requested. Also, consider costs of maintenance and supplies needed for equipment as part of the bid evaluation. Purchases can also be evaluated based upon the methods available for disposal of the item at the end of its useful life. Those methods ranked the highest based upon a source reduction priority are: trade-in for a newer model, resale, and salvage of components for repair or maintenance of like items.

Intergovernmental arrangements for bulk purchasing enhance the economics of source reduction programs. Cooperative purchasing can occur between states or municipalities, or municipalities can piggyback off state purchasing. Municipalities can co-purchase and share equipment (such as a tub grinder) on a scheduled basis.

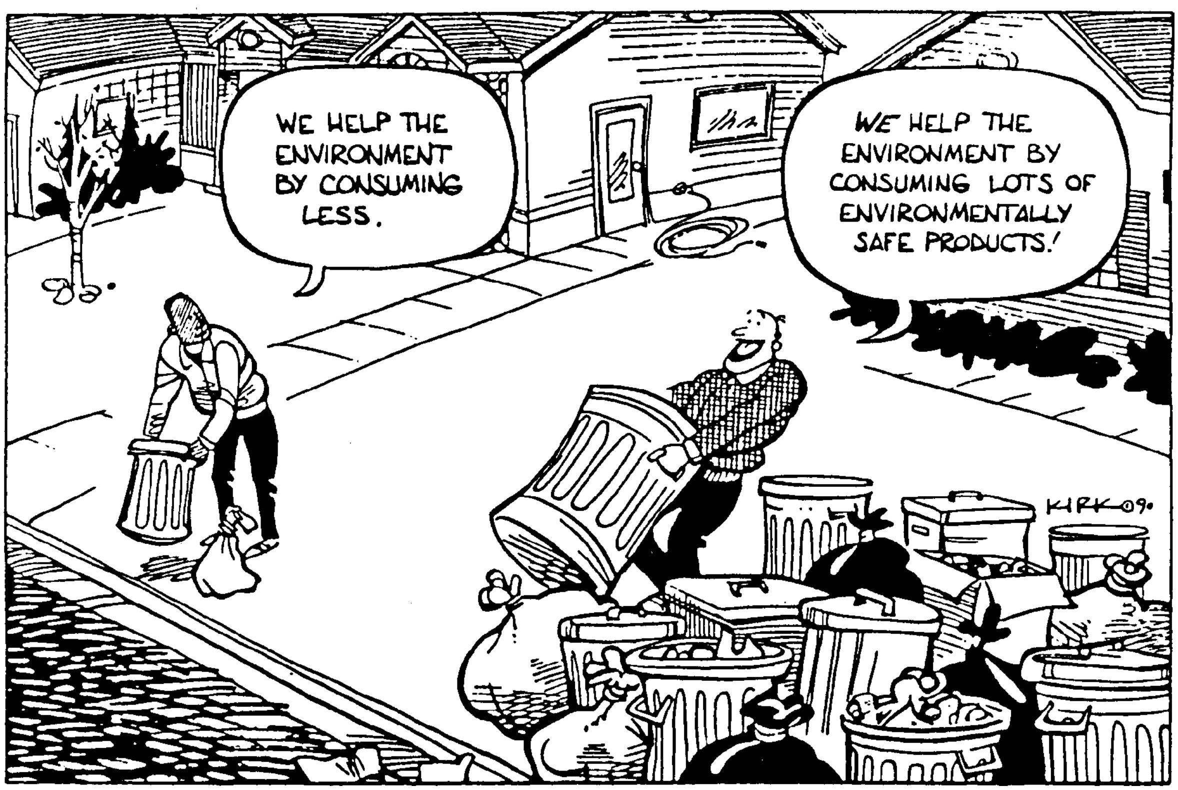
In addition to changing procurement procedures, local governments can consider implementing other source reduction activities.

Purchasing products made with recycled content helps to make recycling a viable process by creating and sustaining markets for used materials, but it is not a source reduction practice. Although recycled products keep otherwise usable materials out of the waste stream, there is a difference between using fewer products overall and using the same or greater amounts of recycled products (see Figure 5-1).

In addition to changing procurement procedures, local governments can consider implementing other source reduction activities, including decreasing yard material at municipal facilities, changing office procedures and employee behavior (for example, implementing two-sided copying), and ordering only the amount of printed materials needed (print on demand), as well as other measures, which are described in the section below on commercial source reduction programs.

Figure 5-1

(Released by Kirk Anderson, Cartoonist)



As a large consumer of paper and materials, the government sector can decrease material use considerably by implementing such measures. For example, Itasca County, Minnesota installed reusable stainless steel furnace and air conditioning filters in 60 units in their garages. Annually, this measure saves 3,120 disposable filters or 53 cubic yards of waste weighing 1,040 pounds. It also saves the county approximately $4,700 per year.

COMMERCIAL (INDUSTRIAL AND BUSINESS) SOURCE REDUCTION

In addition to government source reduction efforts, significant opportunity exists for developing source reduction programs in the commercial, business, and consumer sectors of each community.

Source reduction programs should also be adopted in the commercial, business, and consumer sectors.

Decision makers can encourage individuals and organizations in their commercial sectors to adopt source reduction programs by providing the following:

- model source reduction programs in government facilities
- technical support such as a hot line, waste assessments or training materials, workshops for targeted generators, and resource information
- education about the economic benefits of source reduction
- public/private partnerships
- awards for source reduction.

A source reduction program for businesses might include the components described below:

A source reduction program for businesses might include the components listed here.

1. **Support and policy directives from management:** Such directives indicate commitment and allow company staff the time and resources to measure for and plan a source reduction program, and then to integrate it into company procedures. Incorporate source reduction achievement standards into individual employee job duties, evaluations and/or bonuses.
2. **A waste reduction team or coordinator:** This team or individual develops the source reduction plan, explores alternative materials and options, works with employees to brainstorm for new ideas, implements and monitors the program, and researches new source reduction developments in order to improve or expand the program.
3. **Accounting of materials purchased and waste produced:** A waste assessment will provide information about the types and quantities of materials purchased, used, reused, recycled, composted or discarded, where and how often they originate and are discarded within the business, and the costs associated with them. This information is critical for identifying cost-effective and practical source reduction actions a company can take.
4. **Reduction plan targeting materials and production/practices:** With information from the waste assessment, formulate a plan to do the following:
   - reduce inefficiencies in material and equipment purchasing and use by buying in bulk
   - buy durable products and equipment
   - identify and incorporate alternative materials that are less toxic or less wasteful
   - identify items that can be reused often
   - identify sources of over packaging and avoid or return the packaging or packing material for reshipment
   - offer alternatives to disposables and indicate costs associated with each.

5. **Employee education:** Inform employees of source reduction goals and teach them what they can do to help achieve them. Provide incentives.
6. **Feedback and reevaluation:** Through newsletters, memos, handbooks, bulletin boards, meetings or awards, inform employees of successes as well as areas where more source reduction can be achieved. Inform them of any additions, restructuring, or modifications to the programs.
7. **Produce or sell products designed to be reusable, more durable and recyclable:** Also attempt to incorporate recycled materials as feedstock into products and purchase recycled materials (although this is not source reduction by definition, it is an integral part of a materials management program).

Many guidelines for business source reduction programs are similar to those for recycling programs.

Many of the guidelines for establishing a source reduction program for businesses are similar to those for setting up a recycling program. Source reduction should be the initial focus of business waste management plans with other materials management methods tailored to the resultant smaller (reduced) waste stream. Developing monitoring systems for material, product, and equipment quality and quantity will help to improve production efficiency. This will allow businesses to measure source reduction, monitor program progress, and increase the likelihood that they achieve source reduction goals.

Source Reduction Implementation Guidelines For Industries

To implement a source reduction plan, local governments can teach and encourage industry representatives to do the following:

Source reduction plans can encourage industry representatives to do several things.

- recover plant materials such as solvents, scrap metal, plastic, paper and other scrap, cooling waters, and oil
- reduce plant scrap by increasing production efficiency
- produce only what is needed to fill an order
- reuse pallets and have damaged ones rebuilt
- reuse and refill containers, such as Gaylord boxes, plastic bags, and drums
- return packing materials and pallets, back-haul via trucker, train, barge, or airplane
- reuse packing material
- redesign products to achieve source reduction in packaging and manufacturing materials
- use materials obtained through a materials exchange program in place of virgin feedstock.

Manufacturing Redesign

Making changes in the manufacturing process and product redesign are important source reduction strategies.

Making changes in the manufacturing process itself is an important strategy for achieving source reduction, which industry representatives should be encouraged to consider. An example of manufacturing redesign that successfully achieved source reduction is provided by Ciba-Geigy Corporation, based in Ardsley, New York. The company's McIntosh, Alabama plant produced 2.5 pounds of industrial waste material for every pound of additive, or twenty million pounds of waste a year. The corporation changed each step of the production process and was able to completely eliminate generation of this waste material. The corporation factors disposal costs into production costs; therefore, each department must account for use and disposal of material and has an incentive to reduce.

Product Redesign

Product design changes are another important element of source reduction. Benefits to industry from product redesign include additional cost savings in reduced shipping weight or space, less water usage (from concentrates), and reduced packaging materials and shelf space. Procter and Gamble provides an example of successful product redesign that resulted in source reduction. Changing the configuration of the wheel and cap of two brands of roll-on deodorant made stacking possible, which eliminated the need for additional shelf-stabilizing boxboard packaging containers. The new design uses 80 million fewer cartons, which results in 3.4 million fewer pounds of waste per year and reduces handling costs.

When considering product redesign, be aware of the frequent tradeoffs resulting from the ultimate waste produced by the product.

When considering product redesign, it is important to be aware of and carefully evaluate the frequent tradeoffs resulting from the ultimate waste produced by the product. Assess whether a product can be redesigned into a smaller or more concentrated form, since smaller items are produced with fewer materials. Source reduction is not necessarily achieved, however, if the smaller item is less durable or not repairable, or it is intended for short-term use (unless it is made of the same material as a larger version).

Concentrated products require less packaging material, but if the packaging for the concentrate is neither recyclable, nor significantly different in weight from the packaging for the nonconcentrated product, it might result in as much discarded material. When the source-reduced *nonrecyclable* package results in less overall material in the waste stream, source reduction is achieved. An example is a concentrated fabric softener packaged in a wax-coated paper carton versus the nonconcentrate in a recyclable (HDPE) plastic container. The single-use paperboard container contains 75 percent less material than the recyclable plastic container. In this case the nonrecyclable packaging should be given priority over a larger, recyclable package. The ideal option would be a source reduced product packaged minimally in a package made of recycled material that is also recyclable.

Other Industrial Source Reduction Strategies

Designing for Durability

Longer lasting, energy efficient light bulbs are an example of this. Steel belted tires are more durable than tires without steel reinforcement and therefore need to be replaced less often. In addition, they can be retread for reuse. This results in source reduction. A trade-off occurs, however, because it is currently difficult to recycle steel-belted tires and many end up in the waste stream.

Designing for Reuse

A reusable, collapsible plastic shipping container is one example. These containers nest to save space, are lightweight but strong enough for stacking to save warehouse space, and are recyclable at the end of their useful life. Although the initial costs are high as compared with shorter-lived corrugated shipping boxes and wooden pallets, cost savings can be realized over time from space efficiency and avoided disposal and purchasing costs.

Designing Products to Facilitate Repair

Modular components that can be selectively removed from items for repair increase the cost effectiveness of repair over replacement.

Source Reduction Implementation Guidelines For Businesses

To help businesses implement source reduction programs, local governments can encourage business representatives to adopt a number of source reduction strategies, including the following:

- Copy double sided.
- Use electronic mail.
- Circulate only one copy of printed material (memos, documents); use routing slips indicating who should read it and who has already seen it.
- Establish central document and file areas.
- Reuse paper by making it into scratch pads.
- Reuse and return corrugated boxes.
- Purchase cooperatively; order supplies in bulk with other businesses (for example, cleaning products).
- Establish a materials exchange among other surrounding businesses (for example, merchants in the same mall).
- Sell items in reusable containers.
- Provide items in bulk and encourage shoppers to buy in bulk.
- Provide shoppers with incentives to reuse store packaging.

A California company's polystyrene peanut reuse program is a successful incentive program for reducing packaging.

Table 5-1

Results of the Feather River Company's Polystyrene Peanut Reuse Program

No. of Bags Reused	Volume	Cost Savings
21 / week	11 cu / yd	$ 320
1092 / year	572 cu / yd	$16,640

Source: Feather River Company

An excellent example of the latter strategy is provided by the Feather River Company of Petaluma, California, which distributes body care products packed with polystyrene peanuts. Commercial customers save the peanuts and return them to the truck driver at the next delivery. Feather River Company does not purchase any new polystyrene peanuts. (See Table 5-1).

Another company, Nicolet Instrument Corporation, which produces high tech instruments in Fitchburg, Wisconsin, targeted several materials for source reduction. Based on the results of a waste assessment, they switched to reusable thermal mugs. Nicolet purchased the mugs for employees and had them imprinted with its own recycling logo. The cost savings in materials used and waste generated are provided in Table 5-2 . Other measures adopted by Nicolet include reusing solder and solvents; rebuilding pallets; and purchasing recharged toner cartridges and returning empty ones for refilling.

A Wisconsin company targeted several materials for source reduction and realized significant savings.

Table 5-2

Results of Nicolet's Reusable Mug Program

Materials	No. of Cups/yr	Cost
Single-use cups	216,000	$7,103 annually
Reusable mugs	950	$2,707 one time

Source: Nicolet Instrument Corporation

Different types of businesses can use source reduction strategies that are appropriate for their specific materials use and waste streams. For example, restaurant managers can include the following strategies, in addition to those listed above:

- Use reusable utensils, dinnerware, napkins and place mats in restaurants for in-store serving.
- Sell beverages on tap, in bulk dispensers and in returnable bottles.
- Buy in bulk.
- Reduce single-serving packages for condiments by providing dispensers.
- Ask diners if they want a glass of water, condiments, straw and napkins.
- Evaluate shipping packaging to identify items that could be eliminated or reduced.

A Rhode Island restaurant's source reduction program saves $2,900 annually and reduces disposal by 700 cubic yards.

One restaurant that benefited from such measures is the Brick Alley Pub and Restaurant in Newport, Rhode Island, which formerly served beer in nonreturnable bottles. Their source reduction program consisted of installing a tap as well as purchasing beer only in returnable bottles. These measures resulted in cost savings of $2,900 and disposal reduction of 700 cubic yards annually.

Packaging should protect products from chemical and physical damage. Once this goal is achieved, source reduction decision-making guidelines for packaging professionals should be followed to evaluate each type of package design. Source reduction considerations should be incorporated into all packaging design. To assess packaging, the following should be considered.

Source reduction considerations should be incorporated into all packaging design.

- Evaluate the need for any package at all.
- Decide if any of the package components can be eliminated.
- Assess the use of toxic chemicals and replace them with less harmful chemicals using the smallest amount possible.
- Design a package that is reusable.
- Find ways to reduce the package size. For example, by using the same type of packaging material, but in smaller amounts (by weight); by reducing the size or volume of the package relative to the product it contains; or by substituting a different, recyclable material that weighs less.

Successful source reduction involving packaging materials was achieved by PPG Industries, Inc. of Wichita Falls, Texas, which manufactures float glass that they package with wood. Their source reduction program decreases disposal and purchasing of wood and promotes local small business development. They created a storage area for some of the wood packaging for later reuse and arranged for a local company to rebuild packaging for company use. In the first year, PPG saved 360 of 750 tons per year of previously landfilled scrap wood and purchased 300 tons less of virgin wood. The resulting economic benefits for PPG Industries include the following:

A Texas company saved 360 of 750 tons per year of previously landfilled scrap wood and purchased 300 tons less of virgin wood.

- avoided disposal costs on 360 tons per year
- decreased packaging costs by 15 percent per year on recycled containers over virgin
- market revenues from wood of $2,400.

In addition, the company rebuilding the wood packaging for PPG realized increased earnings of $4,000 monthly and added 2.5 new jobs.

Ideally, it would be economically and technically feasible to recycle packaging when it reaches the end of its reduced and reused life. Packaging designed for reduction and reuse would ideally meet both these criteria, thus helping to achieve further overall waste reduction.

Other Examples of Source Reduction and Reuse by Businesses

- A laser printer service business, Shadow Fax in Madison, Wisconsin encourages reuse through cost incentives and reduction through longer product life. Shadow Fax gives customers a cost credit for return of a laser printer toner cartridge for refilling. The cartridge is disassembled, any worn parts are replaced and it is refilled with new toner. They also rebuild cartridges with more durable parts, increasing their service life more than six times. Although the rebuilt cartridges are the same price as new ones, they are sold 90 percent more often. Cost credit incentive structure: New, in box $89; rebuilt, increased durability $89; recharged without core returned $59; recharged with core for reuse $49.

- Safety-Kleen, the world's largest recycler of contaminated fluids, operates automotive solvents recycling firms throughout the United States. Safety-Kleen developed a container to further reduce and reuse its business material which, in addition, is recyclable when it can no longer be reused. The plastic container for antifreeze, made with recycled plastic resin, was developed for reuse. When antifreeze is brought in for reclaiming, the container is refilled. When the container is at the end of its useful life, it is recycled into another reusable antifreeze container.

  Safety-Kleen also developed a reusable and returnable dry-cleaning bag to replace disposable plastic dry-cleaning bags. More than one billion plastic dry-cleaning bags are landfilled each year. The average cost savings for switching to reusable bags for 125,000 to 150,000 garments per year, or 500 customers per month, is four to six thousand dollars annually. This program also includes hanger reuse and recycling resulting in a 40 percent cost decrease for hangers or up to three thousand dollars annually.

Other companies have also realized savings from source reduction programs.

- Goodwill Industries of America is a nonprofit business that accepts and collects donations of used items such as clothing, small appliances, and furniture, some of which they repair or rebuild. A UCLA-Extension study developed methods to quantify diversion resulting from thrift stores and garage sales. They determined that 11,600 tons were diverted from thrift stores and 57,700 tons from approximately 164,900 garage sales in Los Angeles, California in 1990.

SOURCE REDUCTION BY RESIDENTS

An aggressive source reduction campaign for the residential / consumer sector involves using a variety of approaches, in addition to the regulatory tools described earlier in this chapter. Decision makers can consider using the following:

Source reduction campaigns for the residential/consumer sector use a variety of approaches.

- economic incentives
- education, technical assistance, and promotions
- investment in source reduction tools such as materials exchange databases or providing composting bins.

To illustrate how local decision makers implement these approaches, details of specific source reduction programs targeting the residential sector are provided.

Local Source Reduction Economic Incentives: Unit-Based Garbage Fees

Unit pricing or unit-based garbage collection fees encourage residents to produce less waste.

Unit pricing or unit-based garbage collection fees are economic tools that encourage residents to produce less waste. Municipalities institute a fee for each bag or can of refuse set out for collection. There are a variety of ways to design a pay-per-container system. All require that users pay for the amount of refuse they generate. In such systems, individual residents can reduce refuse collection costs by producing less refuse. This provides an economic incentive for source reduction, recycling and composting. A range of 25-50 percent reduction, primarily due to increased recycling and yard material diversion, has been reported by some communities in the first year unit-based rates are implemented. It is difficult to separate the smaller percent that is attributable specifically to source reduction.

Unit-based container rates make the true cost of solid waste management apparent to consumers.

Unit-based container rates help the resident understand the true cost of solid waste management. The rates usually incorporate the cost of refuse collection and disposal and, in some programs, subsidize recycling collection as well. There is often no extra charge to the resident for increasing amounts of recyclables collected. A flat fee for unlimited amounts of garbage collection and disposal is removed from taxes where is was often hidden under the general tax levy. Or a fee can be charged as a special assessment on taxes or placed on a utility bill to cover a base amount of service only.

Variable rates can be used for both curb-side and drop-off refuse and yard material collection programs. In addition, unit-based rate programs can be either publicly or privately operated. There are a variety of mechanisms for charging fees to residents. These include residents purchasing special trash bags, buying tags or stickers to affix to their own bags and containers, signing up for a specific size and number of cans, and paying by weight of garbage. A variation on these unit-based rate systems is a base rate system. Users all pay a set fee (base rate) for a given amount of service, and then pay per container for any garbage disposed of above the base amount. Limits to the size and weight of bags need to be set to prevent over-stuffing, and illegal dumping provisions in ordinances need to be enforced.

By 1994, more than 2,000 communities had implemented some type of unit-based rate program.

By 1994, more than 2,000 communities had implemented unit-based rate programs. The City of Seattle, Washington instituted unit-based fees in 1981. They used a variable can rate or charge based on the size of can each household signed up for with a mini-can of 19 gallons as the lowest option. Seattle has tested, on a pilot-program basis, a system in which each can is weighed at the truck and the weight recorded with bar code scanning for exact billings.

Because the amount of refuse produced can be reduced by source reduction, recycling, and composting, residents who “pay by the container” have an incentive to choose the products they purchase with each item’s waste potential in mind. Pay-per-container systems encourage source reduction by providing additional economic incentives to buy items with minimal packaging or in reusable containers.

Utica, New York uses unit-based rates for municipal refuse collection. Collection costs for refuse decreased from $1.4 million to $806,000 in one year. Recycling collection costs were an additional $103,000. With the pay-per-container program, the volume of material at the landfill decreased by one third. (Note: the portion of landfill diversion attributable directly to source reduction as opposed to recycling is unquantified.)

Decision makers can learn more about volume-based rates in *Variable Rates in Solid Waste: Handbook for Solid Waste Officials, Volumes I and II* (USEPA Documents) and *Wisconsin Volume-Based Rate Collection Guide* (UW–Extension). USEPA will have a new unit pricing guide by June 1994.

Yard Material Reduction

Managing yard material at home can significantly reduce solid waste.

Local solid waste program managers can encourage residents to promote waste reduction by managing yard material at home. Although in this case the production of grass and leaves is not being reduced, using the material where it is produced rather than adding it to the waste stream is a form of source reduction. Residents should understand that leaving grass on the lawn is beneficial for the lawn. Backyard composting, leaving grass clippings on the lawn, and mulching are all source reduction measures. (These are described further in Chapter 7.) The “Don’t Bag It” campaign created by Plano, Texas has been adopted in eight states including Iowa, Missouri, and Louisiana. Milwaukee, Wisconsin uses a “Just Say Mow” program. Other states use master composter programs, demonstration compost sites, publications, exhibits, and posters to educate the residential and commercial sectors.

Local managers should emphasize the importance of using correct methods of backyard composting so that composting is not perceived as a public nuisance. Distributing guidelines to the public so they can learn how to avoid attracting animals and creating odors will help them to become successful composters.

Master composting programs that teach residents how to build compost bins and make compost can be developed.

Local solid waste program officials can organize master composting programs that teach residents how to build compost bins and make compost. The City of San Francisco contracts with a nonprofit, community-based group (SLUG—San Francisco League of Urban Gardeners) to provide composting information to residents. They provide educational literature, conduct workshops, and staff a "rotline." The village of Skokee, Illinois provided tax rebates on mulching mowers for $25 toward purchase of a new mower or one third the cost of a mulching attachment. Seattle, Washington distributes recycled plastic compost bins free to residents. They expect to recoup the costs of the bins within fifteen years due to avoided disposal costs. Keeping yard material at home can be more efficient for home owners, because it means less work than bagging yard material for collection or hauling it themselves to a drop-off or composting site.

Grasses have been developed that are slow growing and that stop growing at a particular height. Planting these grasses preferentially is an effective source reduction tool for yard material. Planting ground cover and spreading shrubs is another method of reducing the amount of grass produced. These practices can be used by local governments on municipal properties and demonstrated to the public.

Assessing the overall environmental effects of waste reduction strategies is important.

Removing trees or not planting trees to eliminate leaves and branches is not a viable source reduction strategy. It is important to assess the overall environmental effects of waste reduction strategies under consideration. In the case of trees, their positive environmental effects (for example, carbon dioxide intake and oxygen production) outweigh possible problems associated with the waste material they produce. Source reduction measures should not substitute one environmental problem for another or create different, but equally harmful effects.

Consumer-Based "Precycling" or "Eco-Shopping"

Local governments can promote source reduction in the residential sector by developing a strong education program. They can also create directories of reuse services such as rental outlets, repair shops, and outlets for used goods in their community; Seattle's *Use It Again, Seattle* directory and Los Angeles' *Put it to Good Use* are good examples.

"Precycling," or "eco-shopping," refers to the decisions consumers use to judge purchases based on the products' waste implications.

Local programs should also publicize the consumer's role in source reduction efforts, which might include basing decisions about purchases, not only on product attributes and costs, but also on packaging and alternatives to disposal. "Precycling," or "eco-shopping," refers to the decision-making process that consumers use to judge a purchase based on its waste implications. Criteria used in the process include whether a product is

- reusable, durable, and repairable
- made from renewable or nonrenewable resources
- over-packaged
- in a reusable container
- in a recyclable container (though not source reduction, this is part of eco-shopping education).

The impact that consumer behavior can have on source reduction is significant. For example, if 70 million Americans each bought one half gallon of milk in half-gallon containers, they would use 41 million pounds *less* paper and 6 million pounds *less* plastic in one year than if the same number of people bought the same quantity of milk in two, one-quart containers. Additional savings would include $146 million in packaging and one trillion Btu's of energy.

Some local education campaigns promoting precycling and source reduction were developed by Berkeley, California; New York City; and Seattle, Washington. Education efforts teach consumers to follow the 5R/C model: reject, reduce, reuse, repair, recycle and compost. Packaging makes up approximately thirty percent by weight and fifty percent by volume of municipal solid waste. For this fraction of the solid waste stream alone, consumer actions have enormous potential to reduce waste.

A local precycling and source reduction education campaign should include strategies that consumers can easily implement to purchase products based on how the product and packaging will be disposed of after use. Several such strategies are described below.

A local precycling and source reduction education campaign should include strategies that are easy to implement.

- **Bring reusable shopping bags:** The first step in precycling is arriving at the store with one or more reusable, durable shopping bags. An alternative is to take back paper or plastic grocery and shopping bags for reuse.
- **Buy concentrates:** Buying concentrates when available reduces packaging.
- **Buy in bulk:** Buying in bulk reduces packaging and is often preferable. However, buying in bulk achieves reduction only if the item purchased will be used before it spoils and becomes a waste. Consumers should, therefore, purchase items with unlimited shelf life in bulk and perishable items according to the rate of use.
- **Purchase reusable products:** Consumers should have the option of choosing reusable items instead of single-serving or single-use disposables. Reusable items include cloth napkins, wipes and tablecloths, china plates and reusable cups, silverware, rechargeable batteries, refillable razors and pens. Beverages purchased in bulk can be used as individual servings by pouring them into a reusable thermos. Nonrecyclable single-use drink containers result in considerably more waste than using a thermos. Plastic produce bags can be reused at the store. Plastic containers (that are not recyclable as yet), and steel coffee cans are packaging items that can be reused as storage containers in place of new items that might be purchased specifically for that function.
- **Purchase durable and repairable products:** Preferential purchase of durable and repairable products is another source reduction strategy. Evaluating product quality will result in both materials and cost savings over a product's lifetime. Energy-efficient, longer-lasting and replaceable light bulbs are everyday items that are more durable. Larger items such as appliances, cars, clothes and retread tires should be purchased for durability, maintained, and then repaired, rather than discarded. Maintaining items in good working condition, for example, keeping tires properly inflated, will extend their useful lives.
- **Buy secondhand items:** Purchasing secondhand items and donating other items to outlets for resale or reuse achieves source reduction. Shopping at garage sales is an excellent source reduction practice. Some items from Goodwill Industries and similar organizations, such as mattresses and small appliances, in addition to being used, have been repaired and refurbished. This is also true for items such as sports equipment, bicycles, lawn mowers and furniture.
- **Borrow or rent items when possible:** Borrowing or renting items, rather than purchasing them at all, achieves source reduction. If the item will be used only once or for a short time, avoid purchasing it. By borrowing or renting, consumers can test products and brands for efficient purchasing later.
- **Avoid over-packaged items:** Not purchasing products with excessive packaging is another strategy. Although the packaging was produced (and therefore not reduced at the source), when consumers reject excess packaging, it encourages manufacturers to adopt source reduction practices.

- **Be aware of products containing hazardous ingredients:** Consumer source reduction (precycling) education should also include information about the hazard level of products. One of the most significant consumer impacts comes from teaching consumers how to substitute alternative products that do not contain hazardous chemicals, how to identify such products, and how to use fewer of them.

Source reduction can occur when one product is substituted with another that has multiple purposes. If a product containing hazardous chemicals must be used, use one that contains fewer hazardous ingredients and a smaller amount of them.

Several strategies exist to reduce the amount and toxicity of materials purchased.

Teach consumers to purchase only the amount necessary to accomplish a task so no or minimal hazardous waste materials are left over. Common household purchases containing hazardous materials include some types of cleaners, disinfectants, polishes, motor oil, solvents and garden pesticides and herbicides. Seattle distributes "safe cleaning kits" to residents in the region as part of its participation in a Regional Hazardous Waste Management Plan.

Another strategy to reduce the amount and toxicity of materials purchased is to encourage consumers to make a shopping list and a plan. This can help to eliminate impulse buying of items not really needed or of overpackaged, single-serving, convenience products. The plan should include estimates of the amount of an item needed; consumers can then avoid acquiring excess product that may become discarded. Comparison shopping can also achieve source reduction.

Labeling programs in grocery stores are another precycling strategy to encourage source reduction.

Labeling programs in grocery stores represent another precycling strategy that encourages source reduction. Champaign-Urbana, Illinois' model supermarket and Boulder, Colorado's "Stop Waste Before It Happens" campaign at grocery stores both use shelf labeling systems. Such programs can also consist of in-store signage, source reduction information booths, and letter writing campaigns aimed at manufacturers.

The materials from programs described above are resources available to local decision makers for use in modeling consumer source reduction education programs.

REFERENCES

Alderden, J. 1990. "Volume Based Rates, Dream or Nightmare?" *Recycling Today* (November).

Bell, Carole. July 1991. Rhode Island Department of Environmental Management, personal communication.

Bracken, Robert. 1992. "North Carolina County Institutes Sticker System," *BioCycle* (February).

Bregar, Bill. 1991. "Shipping Container Market's Growth Slow," *Plastics News* (September 19).

Brown, Kenneth. 1990. *Examples of Waste Source Reduction For County Government*. Minnesota Office of Waste Management.

Chertow and Cal Recovery Systems. 1991. *Draft Final Report: Waste Prevention in New York City, Analysis and Strategy* (March).

CONEG Policy Research Center, Inc. 1989. *Final Report of the Source Reduction Task Force.*

CONEG Policy Research Center, Inc. 1990. *First Annual Report*.

Fishbein, B. and Caroline Gelb. 1992. "Making Less Garbage: A Planning Guide for Communities," *Inform*.

Gruder, Sherrie. 1993. "Matchmakers: Materials Exchange," *Resource Recycling* (December).

Gruder, Sherrie. 1993. *Wisconsin Volume-Based Rate Collection Guide: Economic Incentives for Source Reduction and Recycling*, (November). UW–Extension Solid and Hazardous Waste Education Center.

Guerrero, Roland. 1991. PPG Industries, Safety, Health and Environmental Control, personal communication.

Harrison, E. & Angell, R. December 1992. *Waste Prevention Tool Kit for Local Governments*. Cornell Waste Management Institute.

Institute of Packaging Professionals. 1990. *Packaging Reduction Recycling & Disposal Guidelines.*

Kashmanian, Ferrand, et al. 1990. "Source Reduction and Recyclability: Recent Market Place Activities," *Resource Recycling* (July).

Lerner, Rosie. 1990. *Response to Yard Waste Resources Survey*. Purdue University.

Minnesota Office of Waste Management. 1989. *Examples of Source Reduction by Commercial Business.*

National Recycling Coalition. 1989. *National Recycling Coalition Measurement Standards and Reporting Guidelines.*

New York City Departments of Cultural Affairs and Sanitation. May 1993. *Starting a Materials Donation Program: A Step by Step Guide*.

Office of Technology Assessment (OTA). 1989. *Facing America's Trash: What Next for Municipal Solid Waste*. OTA-0-424.

Ohio Department of Natural Resources. 1990. *Waste Reduction Guide for Ohio's Business and Industry*.

"Redesigning Packaging to Cut Costs and Waste," *Wall Street Journal*. July 31, 1991.

Rhode Island Department of Environmental Management and Brown University Center for Environmental Studies. September 1992. *Mandatory Commercial Solid Waste Recycling: Rhode Island Case Study*.

Rubin, Powers, et al. 1990. *Industry, Environment Harmonize Through Pollution Prevention*, ENR Construction 2000.

Safety-Kleen. Form 91528.

Skumatz, L. 1991. "Garbage by the Pound: The Potential of Weight-Based Rates," *Resource Recycling* (July).

Skumatz, L. and Breckinridge, C. 1990. *Executive Summary, Vol. I and Detailed Manual, Decision Maker's Guide To Solid Waste Management—Vol. II* (June). NTIS Document Number EPA 910/9-90-102a.

UCLA-Extension. 1991. *Non-Profit Thrift Store and Garage Sale Diversion Study* (June).

USEPA. 1989. *Agenda for Action*.

USEPA. 1990. *Characterization of Municipal Solid Waste in the United States: 1990 Update.*

USEPA. 1992. *The Consumer's Handbook for Reducing Solid Waste*. August.

USEPA. 1993. *Waste Prevention Pays Off: Companies Cut Waste in the Workplace*. September. EPA/530-K-92-005.

USEPA. 1993a. *Business Guide for Reducing Solid Waste*. September. EPA/530-K-92-004.

USEPA. 1994. *Pay-as-You-Throw: Lessons Learned About Unit Pricing.* EPA 530-R-94-004.

World Wildlife Fund and the Conservation Foundation. 1991. *Getting At The Source, Strategies for Reducing Municipal Solid Waste.*

6 ❖

RECYCLING

Recycling, the process by which materials otherwise destined for disposal are collected, processed, and remanufactured or reused, is increasingly being adopted by communities as a method of managing municipal waste. Whether publicly or privately operated, a well-run recycling program can divert a significant percentage of municipal, institutional, and business waste from disposal and can help to control waste management costs by generating revenue through the sale of recyclable materials. Public support for establishing recycling programs continues to grow and some states now require communities to recycle.

Successful recycling is not guaranteed, however. Program managers must give special attention to making the program economically efficient and maximizing public participation. Establishing an effective recycling program presents a major administrative and political challenge to a community. In successful programs, procedures are continually reviewed and adjusted according to changing conditions.

Program managers should continually strive to provide a consistent stream of high-quality (free of contaminants) recovered materials that meet the standards of the marketplace.

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6 ❖ HIGHLIGHTS

Program design and revision are ongoing efforts. (p. 6-1)	Establishing an effective recycling program presents major administrative and political challenges to a community. In successful programs, procedures are continually reviewed and adjusted according to evolving conditions and changing community needs.
Design programs as coherent systems that involve the public in every step. (p. 6-6)	An efficient recycling program requires a systems approach—all program components are interrelated; decisions about one must be made with other components in mind. Successful recycling also requires enthusiastic public participation, and programs must be designed with public convenience and support in mind.
This 12-component plan provides an outline for successful program design. (p. 6-7)	Following a sequential approach can ensure adequate planning and successful program implementation. 1. Identify goals. 2. Characterize recyclable volume and accessibility. 3. Assess and generate political support. 4. Assess markets and market development strategies for recyclables. 5. Assess and choose technologies for collection and processing. 6. Develop budget and organization plan. 7. Address legal and siting issues. 8. Develop start-up approach. 9. Implement education and publicity program. 10. Commence program operation. 11. Supervise ongoing program and continue publicity/education. 12. Review and adjust program.
Successful marketing of recyclables requires • accurate market knowledge • shared decision making. (p. 6-13 — 6-16)	Securing stable, reliable markets requires (1) basing marketing decisions on a clear understanding of the recyclables market system, and (2) sharing decision making among recycling program planners, government officials, the public, and the private sector. Assessing markets involves the following: • *Identifying buyers:* Names, phone numbers and addresses are available from state recycling offices (many produce recycling markets directories). • *Contacting buyers:* Ask about the price they will pay, specifications for how the materials must be prepared, and amount of contamination that is acceptable. • *Selecting buyers:* The buyer's abilities must closely match the recycling program's needs. Some program planners interview prospective buyers. • *Contracting with buyers:* A written contract specifying what is expected of all parties should be made. During market downturns some buyers will only service customers who have contracts.

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Understanding current U.S. and foreign market trends is crucial.

(p. 6-16 — 6-17)

Successful marketing requires an understanding of current trends and changes in domestic and foreign markets. Current trends include the following:

- More communities are developing MRFs (materials recovery facilities).
- Expanding and adding new recyclers as intermediate processing services is becoming more common.
- The improving quality of recyclables makes processing larger quantities more cost-effective and serving markets at greater distances possible.
- Export markets for recyclables are expanding, and direct marketing strategies for exporting recyclables are helping spur the expansion.

Several options for market development can be pursued.

(p. 6-17 — 6-24)

Market development requires balancing supply of recyclables with demand for products made from them. This chapter discusses the following strategies and tools:

- legislative options
- economic incentives
- technology developments and improvements
- transportation networks
- business development
- education strategies
- cooperative marketing.

Program design will be based on answers to these questions.

(p. 6-24)

- What form will the waste be in when it is provided to the collector?
- How will the waste be collected?
- What type of processing/storage facility is best?

Several options exist for preparing recyclables for collection.

(p. 6-24 — 6-28)

Many options exist for preparing recyclables for collection—individual community needs and circumstances determine which is appropriate. These options include the following:

- residential drop-off centers
- residential buy-back programs
- curbside collection
- source separation
- mixed waste collection
- wet/dry collection.

6 ❖ HIGHLIGHTS (continued)

Options for collecting recyclables include both public and private collectors. (p. 6-30 — 6-32)	Options for collecting recyclables may include the following: • using existing public sanitation workers for waste and recyclables • using private haulers for recyclables only • using private haulers for waste and recyclables.
Inner cities and multiple-family dwellings have special collection needs. (p. 6-33)	Inner-city neighborhoods and multiple-family dwellings pose special problems; education programs and buy-back centers may improve participation.
Processing and storage centers can benefit both small and large communities. (p. 6-33 — 6-34)	Small communities or groups of communities may develop small drop-off centers that feed a larger processing facility (see Figure 6-7); each small community, then, benefits from a convenient, low-cost collection point and the economies of scale that a large facility provides. To manage large urban recycling programs, many communities use MRFs (material recovery facilities), which process large volumes of material in the most efficient and cost-effective manner.
MRF designs must consider • space needs • safety • accessibility. (p. 6-33 — 6-34)	There are three crucial considerations in designing a MRF: • The site must accommodate buildings, traffic and storage. • Layout and equipment must facilitate efficient and safe materials processing, movement, and storage in compliance with local building codes. • Design must allow efficient and safe external access and internal traffic flow.
Program organization and budgets. (p. 6-44 —6-46)	*Organization:* To be successful, every recycling program must be run like a business, rely on trained personnel, and have an institutionalized structure within the community. Programs can be purely public (run by public works departments and city councils), public and private (run by sanitary district or recycling commission), or purely private (nonprofit or for profit). For any program, a paid manager and staff with broad business and organizational skills is necessary. *Budget:* The budget should estimate personnel, equipment, building, and other expenses; indicate capital and operating costs for a MRF or collection center; and predict revenues and other sources of income (see Table 6-14). *Financing:* Revenue from the sale of recyclables may be inadequate to cover all program costs. Most communities budget additional tax monies or develop alternative strategies for program financing.

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Program planners must address legal and siting issues. (p. 6-45 — 6-48)	Resolving legal and siting issues during the planning and implementation process is crucial. Overlooking a legal requirement can halt the entire project if a legal challenge arises. Five categories of legal/siting issues are discussed: • zoning and land use considerations in siting • permits • contracts • general business regulation • ordinances.
"Start-up plans" help communities adjust to new programs. (p. 6-48 — 6-49)	All new recycling programs involve major changes in the way citizens handle waste; a start-up plan is, therefore, a must. Communities can start with a voluntary or pilot program, and use information and experience gained from it to plan for a larger-scale recycling program.
Program options can be evaluated during pilot programs. (p. 6-49)	In these programs, materials are collected using prescribed methods for a set period of time; the program's efficiency is then evaluated. Such programs allow communities to test the appropriateness of different strategies to meet their needs.
Starting with a voluntary program helps education. (p. 6-49 — 6-50)	Voluntary programs allow an educational period in which the benefits and strategies of a recycling program are taught. A subsequent change to a mandatory program will be more easily accepted and complied with.
Education and publicity programs should be ongoing efforts. (p. 6-51 — 6-52)	The long-term success of any recycling program depends on public participation. Citizens and local officials must be constantly reminded of the environmental, economic, and social reasons for reducing landfill waste. Program publicity, promotion, and education must be ongoing.

6 RECYCLING

DEVELOPING A RECYCLING PROGRAM: A SYSTEMS APPROACH

In cost-effective and efficient programs, decisions are made with all other program components in mind.

Designing an efficient recycling program requires a systems approach. Decisions about collecting, marketing, and processing recyclables are interrelated. Making a decision about one component of a recycling program without taking into account the impact of that decision on other components may lead to an inefficient and overly expensive program, prone to public criticism and meager participation. Since the public (citizens, families, and businesses) must be relied on to participate by separating a high percentage of uncontaminated recyclable materials, the program must be designed with public convenience and support as a primary objective.

To ensure success, a community recycling program must be developed in a coordinated fashion. First, communities should decide which materials will be recycled. This decision should be based on an analysis of the volume of the community's recyclable material that can be diverted to the recycling operation and the marketability and economics of handling such materials. Once it is known which materials will be collected and in what volume, decisions can be made concerning how to collect the material, what processing will be needed, and how much processing and storage space will be required. The needs of potential buyers will help determine what types of equipment for processing and storage will provide better marketability.

A well-designed recycling operation should have minimal environmental impacts. However, as with any material processing operation, land use and siting issues must be considered and any conflicts resolved. Significant effort must also be made to operate the facility as a good neighbor and keep nuisance conditions, such as noise, from developing.

Finally, a recycling program must be designed to meet the requirements of state recycling legislation. This chapter discusses the key issues involved in developing and operating a recycling program. Steps and procedures are explained within the context of a system with interrelated components.

USING EXISTING RESOURCES

Drawing on local resources can save time and money.

Carefully evaluate what local public and private sectors can offer.

In many communities, private businesses or public agencies may be able to provide the services necessary for planning and implementing a recycling program. For example, a local hauler may own or have access to an existing recycling processing facility, which would eliminate the need for the community to provide its own processing capability. Similarly, recycling consultants can provide expert planning advice, which is especially important for small communities lacking environmental or public works staff.

The extent of outside involvement will depend on community resources and goals and the availability of qualified service providers. The inefficiency and cost of duplicating services should also be considered. The community must make an effort to develop an effective program, but may not need to perform every task internally. Recycling often provides an excellent opportunity for developing partnerships between the public and private sectors.

Cooperative Recycling

Cooperation among communities can benefit a recycling program, and opportunities for such cooperation should always be pursued. Processing recyclable materials from more than one community creates economies of scale for equipment purchase and program administration. Joint marketing of recyclable material can enhance marketability by increasing the volume of material available to buyers.

DESIGNING AND IMPLEMENTING A RECYCLING PROGRAM

Decision making should be well organized and coordinated.

Designing an effective recycling program requires a careful analysis of the variety of technical options available in light of the resources and goals specific to a community. Each community is unique; others can provide ideas, but each community or regional cooperative should develop its own program.

Community decision making should follow a coordinated process. Following a sequential approach reduces the likelihood of overlooking an essential issue or giving it insufficient attention. The long-term success of a program can be jeopardized by inadequate planning or poor implementation.

Regardless of whether or not state recycling legislation is in place, developing and implementing a recycling program should involve a 12-component process, which is outlined in Table 6-1. Components 1, 2, and 3 (identify goals; characterize recyclable quantity, composition and accessibility; assess and generate political support) focus on gathering information and developing the political base needed to determine the scope of the program; they are addressed in detail in Chapters 1, 2, and 3.

Components 4 through 8 (discussed in this chapter) focus on markets and the technical details of the program. Components 9 through 12 (also discussed in this chapter) address implementing the program in the community. By following this systematic approach, program managers will improve the likelihood of program success.

Table 6-1
A 12-Component Recycling Program Plan

1. Identify goals.
2. Characterize recyclable quantity, composition, and accessibility.
3. Assess and generate political support.
4. Assess markets and market development strategies for recyclables.
5. Assess and choose technologies for collection and processing.
6. Develop budget and organization.
7. Address legal and siting issues.
8. Develop start-up approach.
9. Implement education and publicity program.
10. Begin program operation.
11. Supervise ongoing program and continue publicity and education.
12. Review and adjust program.

Source: P. Walsh. 1993. University of Wisconsin–Extension, Solid and Hazardous Waste Education Center

Assess Markets and Market Development Strategies for Recyclables

It is frequently said that the ultimate success of recycling depends on stable, reliable markets for recyclables. Unless a community has markets for the materials it collects, it may end up temporarily storing some materials and later landfilling some or all of them. If citizens are asked to separate materials for recycling and some are subsequently landfilled because markets are depressed or nonexistent, a negative political backlash may result; community support for recycling could fall and the program may be jeopardized. Unless state law requires that certain materials be collected, it may be wise to start by collecting only readily marketable materials for the community collection program.

Securing stable, reliable markets for recyclables is a twofold process. First, it requires marketing decisions based on a clear understanding of the infrastructure of recycling. Second, it demands that recycling program planners, government officials, and the public share responsibility with the private sector in adopting and implementing market development strategies.

STRUCTURE OF THE RECYCLABLES MARKET

The following sections discuss recycling markets and market development strategies from domestic (U.S.) and global perspectives. They also discuss recycling markets and market development trends currently being used and studied, as well as potential barriers to those techniques. After reviewing these sections, the reader should understand how local marketing and purchasing decisions affect, and are affected by, the global marketplace.

Competing in the global recyclables market requires knowledge of handling strategies and their changes.

The tonnage of municipal solid waste recovered for use by U.S. and export markets has increased dramatically over the past several decades. According to the USEPA, almost 6 million tons of materials were recycled in 1960. That figure grew to nearly 30 million tons by 1992. The amount of recyclables available to markets is expected to increase even faster in coming years as recycling programs around the country continue to grow. These significant growth rates will require accelerated attitudinal changes that recognize recyclable materials not as waste, but as raw materials or feedstock for industries with a great potential to affect local, national and international commerce.

Recycling collection and marketing are not new phenomena. Recyclables have been collected from non-municipal sources, especially industry, for a very long time, exceeding one or two hundred years in some cases. Thus, the tonnages of materials separated for recycling are higher from these sources. Table 6-2 reports the 1992 tonnages of recyclables collected from all sources (for which data are available) and marketed to domestic and export users. As shown, nearly 1 billion tons of materials were collected.

Table 6-2

1992 Tonnages of Selected Recyclables

Category	Export Market	Domestic Market
Scrap Paper and Paper Products	6,448,000	27,299,000
Metals: Ferrus/Nonferrous	10,563,000	52,378,000
Plastics	202,000	401,000[1]
Glass[2]	n/a	n/a
Total	17,213,000	80,078,000

[1]Includes tonnage of bottles only.
[2]Tonnages of recovered glass are not tracked.

Sources: *Resource Recycling*, April 1993; *Scrap Processing and Recycling*, May/June 1993

As the quantity of recyclables increases, it will affect the established material-handling network for recyclables in the United States. An understanding of existing material-handling strategies and probable changes to these strategies is important to recycling program planners who want to remain competitive in this emerging global marketplace.

Market Structure

Markets link buyers and sellers for a particular good.

A market is an institution that serves as a link between buyers and sellers of a particular good. In recycling, the market infrastructure includes two tiers: intermediate markets and end-use markets. Intermediate markets are commonly categorized as collectors, processors, brokers, and converters. End-use markets use recovered material as feedstock to manufacture a new product. Companies can serve one or more of these functions simultaneously.

Collectors/Haulers

Collectors are companies that collect recyclables or are waste haulers who have expanded their business to include collecting recyclables from residents and businesses. Most collectors accept unprocessed recyclables, either source-separated or commingled. These materials are commonly marketed to another intermediate materials handler or domestic market; collectors usually do not export materials.

Processors

Processors accept and modify recyclables from residential or business sources by sorting, baling, crushing, or granulating. Processors include local, private buy-back centers, and privately or publicly operated material recovery facilities (also referred to MRFs, pronounced “murf”). These buyers sell to other intermediate buyers or domestic end-use markets and do not generally use export markets. Processors may be material-specific (e.g., processing mixed paper into various goods).

Brokers

Brokers can switch materials from one market to another, depending on demand and other factors.

Brokers buy and sell recyclable materials, often arranging to have them shipped from one location to another by collectors or processors. The broker receives a fee for this service. Depending on the situation, some brokers provide processing services, while others only move preprocessed recyclables. Brokers generally sell to converters or to end-use markets and commonly export materials to foreign countries. The advantage of brokering is that brokers have a variety of markets available to them and can switch materials from one market to another depending on demand and other factors. Sometimes brokers are able to quickly market a slightly contaminated load for a lower price through other market contacts. Brokers may require all materials collected to be marketed through them so that they receive the more lucrative materials as well as materials with higher levels of marketing risk.

Converters

Converters are companies that take recyclable materials in a raw form and alter them so they are readily usable by a manufacturer. An example of a converter is a company that produces pulp from paper; the pulp is then used by a paper mill.

End-Use Markets

End-use markets are public- or private-sector entities that purchase recovered materials from a number of sources and use those materials as feedstock to manufacture new products. Although historically the majority of private-sec-

With direct marketing to end users, communities can avoid market price swings and benefit local manufacturers.

tor markets for U.S. recyclables were in this country, export markets are becoming stronger. Communities may want to market some materials directly to end-use markets. Although direct marketing eliminates the need to pay a broker, the community assumes the risk if the buyer rejects a slightly contaminated load and there is no alternative market readily available. If, however, a community has a well-run program producing high-quality recyclable material, direct marketing can work well. Many communities around the country have established lucrative and stable markets by direct marketing baled newsprint for newsprint. Direct marketing to end users can relieve the community of broad swings in market prices and provide benefits to local manufacturers. As with any product, local marketing must be carefully developed and the materials' value well publicized.

Transportation Companies

Transportation companies nationwide are developing strong business relationships with a variety of industries that market products made from recyclable materials. These transport businesses may be able to guarantee to the community that materials collected by the hauler will be marketed by the hauler. The community and the hauler should negotiate issues such as who will own the recyclables and who will receive revenue for the materials sold. Often communities and haulers share risks and benefits by agreeing to split revenues.

Material-Specific Market Structure

The list of potentially recyclable materials is long, and it continues to grow as technological developments enable more materials to be recycled into more products. To simplify a discussion of these commodities, the list of materials can be grouped into five major categories of postconsumer recyclables: paper, glass, plastics, scrap metals, and waste tires.

Paper

Recovered paper and paper products are bought and sold through well-established local processors and brokers who sell to domestic and export paper mills.

Recovered paper and paper products are bought and sold through a well-established network of local processors and brokers who typically bale these materials for sale to domestic and export paper mills. Increasingly, mills are also buying directly from collectors as well. Table 6-3 presents tonnages of wastepaper recycled by domestic and export markets in 1992. Paper and paperboard represented a significant contribution to export trade in the 1970s, when fiber-poor nations like Japan and South Korea began to add new papermaking capacity and the output of Scandinavian countries (once leading ex-

Table 6-3

Waste Paper in Thousand Tons, 1992

Grade	Domestic Use[1]	Export	Total
Newspaper	5,856	1,285	7,141
Corrugated grades	12,614	2,765	15,379
Mixed grades	3,145	875	4,020
High grades	5,684	1,490	7,174

1. Consumption by U.S. paper and paperboard mills, including producers of molded pulp and other products.

Source: American Forest and Paper Association, 1993

The paper industry has set a recovery goal of 40 percent by 1994. The current recovery rate is 38 percent.

porters) began to decline. Recovered paper is classified as newsprint, corrugated cardboard, mixed paper (including magazines, junk mail, and boxboard), high-grade de-inking (white office paper), and pulp substitute (usually mill scrap).

Paper mills, the most common end users of recovered paper, use the material as a feedstock to manufacture recycled paper and paper products, such as newsprint, chipboard, kraft linerboard, corrugating medium, and tissue products. Other uses of recovered paper include roofing felt and chipboard. Shredded paper can be used to make animal bedding, hydromulch, molded pulp products, and cellulose insulation. The paper industry is making a significant investment in manufacturing capacity for making paper and paper products with recycled content, and has set a recovery goal of 40 percent by 1994. The current recovery rate is 38 percent.

Foreign mills continue to add recycling capacity as well. In fact, the rate of growth in the export of recovered paper has exceeded domestic growth, due in part to the tremendous economic growth and prosperity in the Pacific Rim nations. From 1970 to 1986, the American Paper Institute (now called the American Forest and Paper Association) estimated that U.S. exports of wastepaper rose from 408,000 tons to 3.75 million tons, an increase of 818 percent in just 16 years. Furthermore, it should be noted that fiber-poor countries like Japan and South Korea have some of the most advanced paper-making mills in the world; hence exports of wastepaper should continue to surpass the growth rate of domestically remanufactured paper.

Glass

Glass manufacturers purchase glass containers recovered in the United States for reprocessing into new clear, green, and brown glass jars and bottles. The majority of recovered glass is remanufactured in this country. According to the Glass Packaging Institute and representatives from Owens-Brockway, a small percentage is exported from west-coast and northeast states to Canada and Mexico. Glass is typically broken for size reduction or crushed into cullet and ultimately sold to glass manufacturers as furnace-ready cullet after metal caps and rings, labels, and other contaminants are removed. The glass industry has pledged to increase the percentage of cullet in its manufacturing operations from the present rate of 31 percent up to 70 or 75 percent, given consistent supplies. Alternative markets for glass include glassphalt, art glass, sandblasting, and from postindustrial window pane glass, fiberglass insulation. The state of California recently passed legislation mandating the use of postconsumer container glass in fiberglass insulation.

Recovered glass markets allow very little contamination. Recycling program planners must address this concern for high-quality recovered glass and other commodities.

Markets for recovered glass have been strong and stable for brown and clear containers. Green glass, however, is seldom used to package goods domestically, so fewer companies produce this color and demand is more sporadic. Although the glass industry has made a commitment to increase the demand for recovered glass overall, there is an important and pervasive market concern about the quality of material being produced by collection programs and at processing facilities. Recovered glass markets usually require very little contamination. Recycling program planners must address this concern for high-quality recovered glass as well as for other commodities.

Plastic

Postconsumer plastic-resin recycling technology has developed more rapidly than technologies for any other recovered material in the last half century. (Note that *postindustrial* plastics have been successfully recycled for years.) Whereas only five to ten years ago postconsumer high-density polyethylene (HDPE) and polyethylene terephthalate (PET) plastics were vaguely considered recyclable, these two resins, especially HDPE milk jugs and clear PET plastics, now hold a stronger place in the market. However, according to many in the plastics industry, the outlook for colored PET and HDPE is uncertain because demand is presently not keeping pace with supply. The recyclability of other resins, such as polystyrene, polyvinyl chloride, low-density polyethylene, polypropylene and mixed plastic resins is making strides but much remains to be done. Table 6-4 provides data on plastics recycling from 1990 to 1992.

The market structure for plastics is the least developed among recyclables because of the recency of recycling capabilities.

The market structure for plastics is the least developed among recyclables because of the recency of recycling capabilities. However, most plastics are densified locally by flattening, baling, or granulating, and sold either to converters, where the resins are turned into pellets, or directly to domestic or export end users for remanufacture into such products as soda bottles, lumber, carpet and carpet backing, flower pots, and insulation.

Metals

Ferrous and nonferrous metals have been bought and sold through a well-established network of processors and brokers and shipped to domestic and export markets throughout the last century. With few exceptions, this long-standing track record makes ferrous and nonferrous metal markets among the most stable of the recyclable materials. Ferrous scrap includes autos, household appliances, equipment, bridges, cans, and other iron and steel products. Nonferrous scrap metals include aluminum, copper, lead, tin, and precious metals.

Ferrous and nonferrous metals can be prepared for sale through some combination of processing by flattening, baling, and shredding.

Both ferrous and nonferrous metals can be prepared for sale to markets through some combination of processing by flattening, baling, and shredding of the material. In some cases, processors melt the metal into ingots before selling it to end-use markets. Concern over polychlorinated biphenyls (PCBs) in capacitors and chlorofluorocarbons (CFCs) in appliance cooling systems has caused changes in appliance handling systems since the late 1980s and may continue to do so for some time.

The development in 1988 of the Steel Can Recycling Institute, now called the Steel Recycling Institute, has helped strengthen demand for postconsumer steel cans. Since that time, several foundries and steel mills have begun or expanded recycling efforts; steel mini-mills also appear to be increasing their use of recovered steel in regions which typically lack large mills. However, the strength of the postconsumer steel can market will vary regionally into the future.

Tires

Tires represent a special challenge to solid waste and recycling program managers.

Tires represent a special challenge to solid waste and recycling program managers. In the past most tires were retreaded, but with the advent of steel-belted radials and cheaper new tires, fewer tires are being retreaded.

Table 6-4

Plastics Packaging Recycling: 1990-1992 (in millions of pounds)

Item	1990	1991	1992
PET	226.7	292.8	402.1
HPDE	160.2	277.2	416.7
LDPE/LLDPE	42.5	41.8	63.5
PS	12.9	23.9	31.6
PVC	1.5	1.6	10.2
PP	0.4	5.2	15.2

Source: R.W. Beck and Associates, 1993; *Plastics News*, July 5, 1993

Scrap tire recycling and disposal has tripled from 1990 to 1992 and may exceed the annual supply of scrap tires generated by 1997.

In the United States, recycling and disposal of scrap tires has tripled from 1990 to 1992 and is expected to exceed the annual supply of scrap tires generated by 1997.

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 requires states to meet minimum utilization requirements for asphalt containing recycled rubber in federally funded transportation projects; states not meeting the minimum requirements will lose a portion of the federal highway funding. By 1994, 5 percent minimum recycled rubber content is required, rising to 20 percent by the year 1997.

As Figure 6-1 shows, using chipped or shredded tires as a fuel source is also growing. Electricity-generating facilities, pulp and paper mills, and cement kilns are the most common processes using these scrap tires.

ASSESSING MARKETS

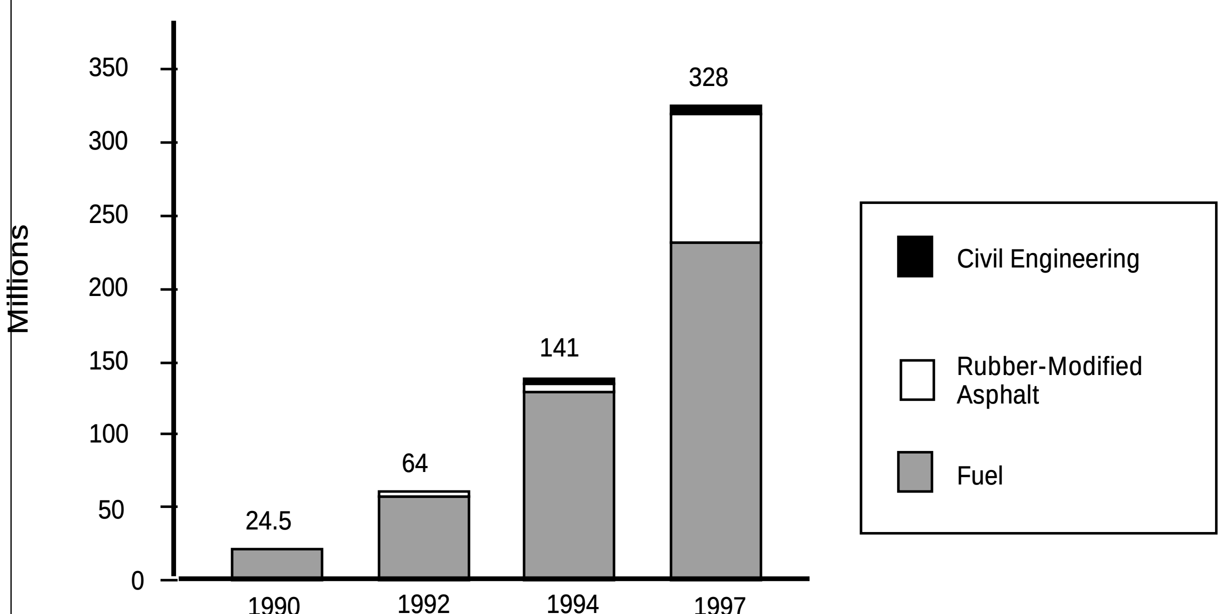
Over time, the ability to consistently sell materials to a buyer may be more important than the price they offer.

When assessing markets for recovered materials remember that, over time, the ability to move materials to a buyer on a regular basis may be more important to the success of the program than the price paid. Developing a relationship with a buyer who will attempt to provide a stable market for customers during poor market conditions is essential to the success of the program. Some communities sell to “spot” markets, jumping from buyer to buyer depending on which company is giving the best price at the time. While this method may increase revenues in the short run, a community with no loyalty to its buyers can expect no loyalty in return from its buyers during downturns in the market. For the marketing of most materials, communities are better served by establishing long-term relationships with reputable buyers.

There is no simple way to determine the best market situation for a given material. This task requires a four-step process which includes identifying, contacting, selecting, and contracting with buyers.

Figure 6-1

Uses of Scrap Tires



Source: Scrap Tire Management Council 1992

Identifying Buyers

For each commodity, a range of available buyers must be identified and contacted.

For each commodity under consideration, a range of available buyers must be identified and contacted. This is tedious but extremely important work. There are numerous methods for finding out which buyers might be willing to purchase or accept your recyclables. Three common methods which have proven successful include company phone calls, visits, and requesting written information or proposals from potential buyers.

The names, phone numbers, and addresses of recycling buyers willing to provide service to communities can be found in a number of places. Many state recycling offices produce a recycling markets directory which can be obtained at little or no cost. Other sources of market information include talking to other recycling program operators, or contacting national industry organizations, such as the American Forest and Paper Association, the American Plastics Council, or the Steel Recycling Institute, as well as privately produced recycling market listings. Names and addresses for these contacts are included in Table 6-5.

Sufficient time and resources should be devoted to identifying markets.

Sufficient time and resources should be devoted to identifying markets for recovered materials. In communities without recycling coordinators or solid waste managers, the task of collecting market information may best be assigned to a committee, with each committee member agreeing to obtain information for a given material. By dividing up the work, the information can be collected efficiently, without burdening any individual.

Contacting Buyers

Know the specifications for presenting the material to the buyer and the acceptable degree of contamination—cleaner materials are more valuable.

When each potential marketing representative is contacted, in addition to asking what price the marketer is willing to pay for the material, other essential information should be solicited. Most important are specifications for how the material must be presented to the buyer and what degree of contamination

Table 6-5

Selected Organizations Providing Market Listings (free of charge)

Glass
Glass Packaging Institute
1801 K Street, NW, Suite 1105L
Washington, DC 20006
202/887-4850

Plastics
American Plastics Council
1275 K Street, NW, Suite 400
Washington, DC 20005
800/2HELP-91

Paper
American Forest and Paper Association's
"PaperMatcher"
260 Madison Avenue
New York, NY 10016
800/878-8878

Metals
Aluminum Association
900 19th Street, NW, Suite 300
Washington, DC 20006
202/862-5100

Steel Recycling Institute
Foster Plaza 10, 680 Anderson Drive
Pittsburgh, PA 15220
800/876-SCRI

General Information
Institute of Scrap Recycling Industries
1325 G Street, NW, Suite 1000
Washington, DC 20005
202/466-4050

Most state recycling agencies maintain a markets directory. Also, statewide nonprofit recycling organizations often perform a similar service.

NOTE: This listing is not intended to be comprehensive. Inclusion on this list does not indicate an endorsement by the USEPA or the document's authors.

Source: M. Kohrell. 1993. University of Wisconsin–Extension, Solid and Hazardous Waste Education Center

As competition increases, programs meeting buyers' specifications will have more secure and stable markets.

(i.e., foreign material) is acceptable. In the case of newsprint, many marketers will pay a different price depending on whether the material is baled or loose. Also, material that is wet from rain or snow or discolored by the sun may be unacceptable to the buyer. In general, the cleaner the material, the more valuable it is, both in terms of price and marketability. Information concerning price and specifications will determine other program components such as storage space needed and whether processing equipment needs to be purchased. These are important decisions with potentially significant financial impact and they should only be made with complete information. As market competition increases, those recycling programs able to effectively and regularly meet buyers' specifications will be assured a more secure and stable market for the collected materials.

Transportation costs are extremely important, so ask company representatives if buyers will provide transport if materials must be delivered.

Transportation costs are extremely important in the economics of recycling, so company representatives should be asked whether buyers will provide transport for collected materials or whether the materials must be delivered. If the buyer will provide a vehicle to collect recyclables, it is important to clarify who pays for the hauling, what tonnage is required, and who loads the collection truck. Some marketers will provide containers, such as semi-trailers or Gaylord boxes (heavy corrugated boxes open at the top, measuring 4 feet by 4 feet by 4 feet) for storage, and will pick up the materials when a full semitrailer load is collected. Some buyers will also have equipment to process the materials and will recover these costs by paying a lower price for the materials. If the buyer does not provide transportation services, recycling program planners must make arrangements with an alternative hauling service.

It is important to determine whether marketing representatives will pay higher prices for higher volumes of materials. Often, if a buyer can be guaranteed a high volume of quality recyclable material on a regular basis, the buyer will pay a premium price. Likewise, communities should determine whether there are minimum quantities that the market will accept.

Check references and past records of buyers and market representatives.

Market representatives should also be asked to provide references for other programs they have serviced. Also, discuss buyers' reputations with other recycling programs in the area. Ask about buyers' track records for providing prompt pick-up and payment, how well they adhere to contracts they have signed, how long they have been in business, and their financial viability.

The revenue offered or charge assessed by a potential buyer should only be considered in relation to the criteria discussed above; revenue cannot be considered as the only or most important criteria. Quoted prices can be compared with general price and trend information provided by industry publications. See Table 6-6 for a listing of price-tracking publications.

Selecting Buyers

The process of selecting buyers begins with evaluating information collected during the waste characterization effort. The objective should be to select buyers whose abilities most closely resemble the needs of the recycling program. Information gathered from potential buyers can be informally evaluated by a recycling employee or planning committee, or a formal evaluation process can be designed. Some recycling program planners schedule interviews with potential buyers to ask specific questions of each. The results are analyzed and the best buyers are selected. Another option is to establish a scoring system that assigns to each buyer a certain number of points based on a set of criteria. The buyers with the highest score are then selected.

Contracting with Buyers

Once buyers have been selected for one or more recyclables, an agreement is commonly negotiated so that each party (the seller and the buyer) knows what is expected of them. While many sellers and buyers have traditionally done business with a "hand-shake" agreement, a written buyer / seller agreement is necessary to protect the relationship with the buyer as competition for markets continues to escalate. Contracts can be particularly useful documents when markets take a downturn because buyers may only service customers with written contracts. Types of written agreements offered by buyers include letters of intent to purchase material and formal contracts.

Provisions included in a written agreement may include tonnage and volume requirements, material quality specifications, provisions for delivery or pick-up, termination provisions, length of commitment, and the pricing basis.

ANTICIPATED CHANGES IN U.S. AND EXPORT MARKETS

Many private recyclers have been in business for generations and understand all too well the intricacies of the recycling market. Conversely, involvement in operating a recycling program is, for the most part, a relatively new enterprise for the public sector.

Using MRFs and intermediate processing facilities is increasing nationwide.

A recent trend in the United States is the development of hundreds of processing facilities, called material recovery facilities (MRFs) or intermediate processing centers (IPCs), which accept commingled (mixed) recyclables and process them to market specifications. In early 1990, close to one hundred such facilities had been established; by the mid-1990s, more than a thousand could exist. These facilities are financed with public or private funds, and operation is provided by some combination of the public and private sectors. MRFs and IPCs provide large governments and groups of smaller governments with cost-effective mechanisms to control their own processing strategies, as well as an opportunity to sell materials directly to end-use markets.

A second trend is the expansion of existing capacity and the addition of new private recyclers to provide intermediate processing services. It is a re-

Table 6-6

Commonly Used Price-Setting and Tracking Publications

PAPER	PLASTIC	METAL
Fibre Market News GIE Inc. Publishers 4012 Bridge Avenue Cleveland, OH 44113 216/961-4130 800/456-0707	Modern Plastics McGraw-Hill Publishers Co. P.O. Box 602 Heightstown, NJ 08520 609/426-7070 800/257-9402	American Metal Market 825 7th Avenue New York, NY 10019 212/887-8560
Official Board Markets "The Yellow Sheet" 1 E. 1st Street Duluth, MN 55802 218/723-9355 800/346-0085	Plastics News Crain Communications, Inc. 965 E. Jefferson Avenue Detroit, MI 48207 313/446-6000 800/678-9595	Iron Age Hitchcock Publishing Co. 191 S. Gary Avenue Carol Stream, IL 60188 708/665-1000
The Paper Stock Report McEntee Media Corp. 13727 Holland Road Cleveland, OH 44142 216/362-7979		MULTI-MATERIALS Materials Recycling Markets P.O. Box 577 Ogdensburg, NY 13669 800/267-0707
		Waste Age's Recycling Times 5615 W. Cermak Road Cicero, IL 60650 202/861-0708 800/424-2869

Most state recycling agencies maintain a markets directory. Also, statewide nonprofit recycling organizations often perform a similar service.

NOTE: This listing is not intended to be comprehensive. Inclusion on this list does not indicate an endorsement by the USEPA or others.

Source: M. Kohrell. 1993. University of Wisconsin–Extension, Solid and Hazardous Waste Education Center

sponse to two factors: (1) the growing number of municipal programs and retail businesses without the capability or desire to become involved in material processing, and (2) the need to consistently meet material quality specifications required by markets. Additional processing capacity will be particularly popular for commodities such as glass and plastics, for which tightening quality requirements make beneficiation necessary before the material can be used by the end-use market.

Selling materials to distant U.S. and foreign markets will become more commonplace.

Growth in the quantity of available recyclables will offer both the public and private sectors the ability to accumulate and cost-effectively process greater tonnages of these materials. This trend will allow materials to be transported to markets at greater distances than in the past. Thus, selling materials to distant markets in the United States and other countries will become more commonplace than is already the case in many locations. An analysis of export data for recyclables indicates that markets in Canada and Mexico are relying more heavily on U.S. recyclables as raw feedstocks than in years past. In addition to these two border countries, the Pacific Rim will continue to dominate the marketplace for west-coast exports. However, as European countries continue to increase their recovery rates, the United States will be forced to compete for Pacific Rim markets.

While private-sector brokers have historically marketed wastepaper and scrap metal to export markets, exports will include more materials, such as glass and plastic. In addition, big-city public-sector recycling staff near east- and west-coast ports of export, such as those in San Francisco, the Washington D.C. area, New York City, and Los Angeles, have made efforts to establish a rapport with export markets to explore the possibilities of direct marketing.

ASSESSING MARKET DEVELOPMENT INITIATIVES

Market development for recyclables involves balancing

- *the supply of recyclable materials*
- *the demand for products made from them.*

Market development involves the attempt to create an even balance between the supply of recyclables and demand for products manufactured from those materials. Just as each recyclable material has unique marketing characteristics, so market development initiatives vary by material. Depending on the material, strategies can be demand-directed, supply-directed, require more stringent material specifications, or be a combination of two or more types of strategies.

While material-specific actions are an important factor in market development, such actions need to be carried out in the framework of broader categories of market development tools. An understanding of strategies being undertaken at federal and state levels is important, along with knowledge of local activities that can favorably impact market development. This section provides information on seven categories of actions currently being undertaken by the public and private sectors at the national, regional, state, and local levels. It also suggests effective strategies to implement at the local level. After reviewing the information in this section, the reader should understand that a philosophy of “think globally, act locally,” is essential to market development for recyclables and recycled products.

Legislative Options

Legislative activities being considered or undertaken by federal, state, and local governments to promote market development are a combination of supply-driven and demand-driven initiatives.

A study conducted for the U.S. Environmental Protection Agency by Franklin Associates Ltd. found that very few local and state recycling program managers know with any certainty the tonnage of recyclables being collected in those programs. Until a structured tracking system is in place, there will be a twofold problem: (1) recycling markets may hold back expansions until

Supply-side legislation, particularly mandatory recycling laws and disposal bans, was in effect in 39 states and the District of Columbia in 1992.

Careful attention should be given to keeping detailed records for tracking the supply of each commodity sold to buyers.

knowledge of guaranteed tonnages is available, and (2) the impact of additional quantities of recyclables on the marketplace cannot be projected.

Supply-side legislation, particularly mandatory recycling laws and disposal bans, was in effect in 39 states and the District of Columbia in 1992. Twenty states require preparation of recycling plans, seven states and the District of Columbia mandate source separation of one or more materials, and 12 states take an intermediate approach. These laws included numeric recycling rates mandating that between 25 and 70 percent of state wastes be recycled, with deadlines ranging from 1991 to 2010. In many cases, local government goals surpass state-mandated levels.

The ability to guarantee private-sector processors and manufacturers reliable supplies of quality recyclables will promote market development. As local recycling program planners and government officials implement recycling programs, careful attention should be given to keeping detailed records for tracking the supply of each commodity sold to buyers. Tonnage information can be added to state and federal tracking systems, when they exist, to inform private-sector businesses of the supply they can expect. Local governments can also pass legislation mandating certain percentage goals or banning disposal of certain items.

Regulatory initiatives designed to encourage increased demand for recyclable materials include recycled content mandates, environmental standards, recycled product labeling laws, and requirements to procure recycled products.

Legislation mandating recycled content in consumer products has been popular in recent years. As a result of certain economies of scale attainable at the state level, the focus of such legislation has rested with state governments or coalitions of state governments. Table 6-7 shows that laws mandating recycled content in newsprint had been passed in at least 11 states by 1992. Recycled content mandates have also been passed for trash bags, glass containers, plastic containers, and telephone books, among other items. National organizations, such as the National Recycling Coalition and the American Society for Testing and Materials, have focused efforts on devising nationwide voluntary standards for recycled content in various products. Adoption of such standards aids manufacturers in making products that meet broadly accepted recycled content levels.

An environmental regulation related to demand for recycled products is the federal Food and Drug Administration's (FDA) prohibition against using recycled plastic resins in new food containers. Continued investigation into

Table 6-7

Examples of Recycled Content Mandates

	Newsprint	Glass Containers	Plastic Containers	Trash Bags	Telephone Books
Arizona	50.0% by 2000				
California	50.0% by 2000	65.0% by 2005			10.0% by 1993[1]
Connecticut	50.0% by 2000			30.0% by 1991	40.0% by 2001
Dist. of Columbia	40.0% by 1998				
Illinois	28.0% by 1993				
Maryland	40.0% by 1998				
Missouri	50.0% by 2000				
N. Carolina	40.0% by 1998				
Oregon	7.5% by 1995				
Rhode Island	40.0% by 2001				
Wisconsin	45.0% by 2001		10.0% by 1995		

1. The 10% goal applies to bags 1.0 mil thick; the 30% goal applies to bags .75 mil thick.

Source: National Solid Wastes Management Association, 1992; *Resource Recycling*, 1993 safety issues by the FDA has opened this market avenue. Several companies have received certifications of “no objection” from the FDA to use recycled plastic content in food containers. For example, several companies are now manufacturing new PET soda bottles from recycled PET. While not a direct approval, this type of environmental regulation is a step toward improved markets for some materials.

Recycled-product labeling regulations can help create demand, but inconsistent state standards create interstate marketing problems.

Recycled-product labeling regulations can help to create demand for recycled products. However, different standards for such labeling in different states creates an inherently complex problem because most products are sold across state boundaries. The Coalition of Northeast Governors (CONEG) and the Northeast Recycling Council (NERC) organized ten states in an attempt to coordinate labeling efforts on a regional basis. Other notable, moderately compatible, actions have been taken by Rhode Island, New York, and California to define standards for labeling recycled products.

Government procurement of recycled products can affect the demand for such products.

It also serves as a positive example to consumers.

According to a study by the National Institute of Governmental Purchasing, state and local government purchasing makes up 12 to 13 percent of the nation’s GNP. With this much purchasing power, government procurement of recycled products can indeed affect the demand for such products. In addition, procurement of recycled products by federal, state, and local governments can serve as a positive example to consumers. Several state purchasing programs provide cooperative purchasing programs that local governments and other public entities can access.

Virtually every state has legislation requiring recycled product purchase. Many states require certain percentages of recycled content; some allow for price preferences. Numerous local governments have laws with goals surpassing their states’ laws. Printing and writing papers are often the focus of much of this legislation, since so much of it is used in the office setting. Cooperative purchasing agreements, mainly focusing on paper products, have been implemented by numerous multi-state entities.

USEPA has published procurement guidelines for purchasing several types of recycled products.

On May 1, 1995, the Environmental Protection Agency issued the "Comprehensive Guideline for Procurement of Products Containing Recoverable Materials" (CPG) (60 Federal Register 21370) and its companion piece, the "Recovered Materials Advisory Notice" (RMAN) (60 Federal Register 21386). The CPG designates 24 recycled-content products in seven product categories. The RMAN provides recommendations for purchasing the products designated in the CPG. Through use of these guidelines, the federal government hopes to expand its use of products with recovered materials, and to help develop markets for them in other sectors of the economy. By May 1, 1996, all government agencies and government contractors that use appropriated federal dollars to purchase the designated items will be required to purchase them with recycled content. For information, call the RCRA Hotline, 1(800) 424-9346.

There are several legislative mechanisms that local governments can use to positively influence the demand for recyclables. First, local governments can pass legislation showing voluntary or mandatory preference for products with recycled content. Governments can also effectively promote the use of recycled product labeling standards that are consistent with those at the state level. Finally, local governments can lead with their actions by adopting purchasing specifications that favor the purchase of recycled products, and following through on those specifications. A list of suggested methods for locating recycled product suppliers is included in Table 6-8.

Economic Incentives

There are economic benefits for using virgin materials in the U.S. that distort the value / cost of these materials. In some cases an advantage is given to virgin materials, for example, through depletion allowances in the tax code and tax credits for virgin materials. Altering these existing economic incentives might involve more readily providing recyclers with tax incentives, rebates, and grants and loans.

Nearly half of all states offer some form of tax credits that can assist recycling.

Nearly half of all states offer some form of tax credits that can assist recycling. Property tax exemptions are provided for buying new recycling equipment in Indiana, Kentucky, North Carolina, Pennsylvania, and Wisconsin. Sales tax exemptions are given in Iowa, Illinois, New Jersey, and Wisconsin to help processors or manufacturers purchase new recycling equipment. Individuals and corporations in Oregon receive income tax credits for capital investments in recycling equipment and facilities; Arkansas, California, Maine, New Mexico, and Delaware also provide income tax credits. Tax-exempt bond financing for building processing and manufacturing facilities has been used by many local governments. Transportation tax credits or exemptions for carriers of recyclables are being used in Washington and Maine to help make hauling materials to market cost effective. Local governments can offer property tax exemptions to recycling-related businesses wanting to locate or expand locally. Another incentive is to sell or lease land or equipment to recyclers at no or low cost.

Approximately two-thirds of all states offer grants and loans to help improve recycling market economics.

Approximately two-thirds of all states offer grants and loans to help improve recycling market economics. Rebate programs to reimburse companies for the recyclables they use or the money invested in recycling equipment can be very effective market stimulators. In Wisconsin, manufacturers who use secondary materials can qualify for rebates of several hundred thousand dollars. Utah pays tire recyclers $21 per ton for tires made into new products or energy.

Grants, loans, and loan guarantees provide new or existing businesses with necessary capital at no or low cost. These incentives are quite popular with private industry. For example, grant programs in Minnesota, Michigan, New York, and Wisconsin will fund demonstration projects or established technologies. Indiana gives priority to the recycling industry for state economic development grants. Loans and loan guarantees—used in Minnesota, New Jersey, New York, Pennsylvania, and Vermont—can provide low-interest capital for businesses. Such loans may be especially helpful for small and minority business enterprises.

Technology Developments and Improvements

Technology developments, more than any other market development initiative category, tend to be material specific. This section provides an overview of some recent developments that have assisted or may assist recycling markets.

Table 6-8

Creating Demand for Recyclables: Purchasing Recycled Products

To ensure a market outlet for your recyclables, purchase products made from those materials. This table outlines three possible methods.

1) Talk to potential markets. Is there a recycled product they make that you could purchase? If so, such reciprocal arrangements are a great way to stimulate your market. Examples: government purchase of recycled plastics curbside recycling bins from the company it will sell plastic to; convincing the local newspaper publisher to buy recycled newsprint from a paper mill who will, in turn, buy your recyclable newsprint.

2) Check listings of recycled products to learn what products are available. Many office supply catalogues now contain a recycled product section. Other listings:

- Buy Recycled Paper Products Guide
National Office Paper Recycling Project
U.S. Conference of Mayors
1620 I St., NW, 4th Floor
Washington, DC 20006
202/293-7330
- Guide to Buying Recycled Printing and Office Paper
Californians Against Waste Foundation
926 J Street, Suite 606
Sacramento, CA 95814
916/443-8317
- The Official Recycled Products Guide
P.O. Box 577
Ogdensburg, NY 13669
800/267-0707

3) Talk to the "Buy Recycled" Program Director with the National Recycling Coalition at 202/625-6406. Or talk to the Procurement Coordinator for Recycled Products at your local state agency. Many state coordinators maintain lists of recycled product suppliers under state contract.

Source: M. Kohrell. 1992. University of Wisconsin–Extension, Solid and Hazardous Waste Education Center

Several technological breakthroughs are encouraging additional demand for fibers.

Markets for fibers have had several technological breakthroughs that will encourage additional demand. While most markets prohibited magazine recovery until as recently as mid-1991, industry analysts predict that demand will outstrip supply for the foreseeable future, thanks to a flotation de-inking technology, developed in Europe about 10 years ago and recently adopted in the United States, that requires a mix of 10 to 30 percent magazines with old newsprint. Several new and converted paper mills in the United States and other countries, notably Canada, should create a stable market for magazines. In another fiber technology development, manufacture of recyclable self-adhesive sticky labels will create a more stable market for office wastepaper. The new technology would eliminate machine-gumming and paper-tearing contamination problems encountered when attempting to recycle self-adhesive labels now in use. Finally, new rules for designs of corrugated containers will allow production of lighter weight containers with an increased content of recycled fibers.

Recent developments among manufacturers have created competition between detinners, foundries, and mills, and have strengthened markets.

The work of the Steel Can Recycling Institute (SCRI) in 1988, now called the Steel Recycling Institute (SRI), has assisted in boosting market capacity for tin-plated steel and bimetal cans at detinning facilities, foundries, and steel mills. While the development of detinning facilities capable of handling post-consumer cans was an initial focus of SRI, recent developments among manufacturers have created unanticipated competition between detinners, foundries, and mills, and have strengthened markets. In response to an SRI promotion, the steel industry, which historically considered the tin plating on steel cans a contaminant, conducted highly successful pilot efforts to use steel and bimetal cans in the remanufacture of steel. Such technological developments will continue to expand across the country.

In the late 1980s and early 1990s, plastic recycling technology developments led other material market developments. Mixed-plastic resin recycling applications have seen some growth recently with the development of the plastic lumber. With the new technology, resins are extruded into various lumber and lumber-like products. The success of these products now depends on the development of standards for plastic lumber, the ability of producers to market the lumber, and on consumers' willingness to purchase the lumber or products made of this material. Problems with contamination of PET bottles by similar-looking polyvinyl chloride (PVC) bottles have jeopardized some plastic recycling programs. The recent development of an improved flotation system designed to remove PVC from the PET recycling stream, along with high-tech developments using x-ray fluorescence and computer scanning, should help advance plastic recycling. Finally, collection and processing equipment developments aiding the recycling of resins such as polystyrene and high- and low-density polyethylene bags will encourage plastic markets.

Public/private partnerships providing funding and guaranteeing supplies of recyclables spur technology developments.

Part of an ongoing continuum, technology developments such as those described above depend on effective public/private partnerships that provide funding opportunities and guarantee supplies of recyclables. Consumer demand, government research and regulations, and private-sector initiatives will necessitate continuing these efforts.

Local governments can encourage businesses to adopt new technologies.

Local governments can work with businesses to encourage them to adopt new technologies that will advance local recycling markets; providing financial assistance when possible will be an additional incentive. Guaranteed supplies of recyclables, along with guarantees from local governments or businesses to purchase products manufactured with local recyclables, can also be an incentive. Use of a local linkage principle as a market strategy will continue to grow in importance.

Transportation Networks

Development of better truck, rail, and overseas transportation networks to move recyclables to domestic and export markets may strengthen markets for many recyclables.

As tonnages available and distances traveled grow, a better truck transport infrastructure is needed.

Loads of recyclables have long been hauled in open-top dump trailers, box trailers, and other long-distance, over-the-road vehicles. However, as tonnages available and distances traveled grow, a better truck transport infrastructure is needed. In addition, haulers must be given access to containers and scales outside of traditional business hours. Recycling program planners and transportation coordinators are making concerted efforts to arrange for backhauls to move recyclables; these efforts should continue. (A backhaul is the return leg of a distance-carrier's journey, so named because it is a load hauled on the way back to the point of origin.) Backhauling provides more cost-effective transportation because recyclers only pay for a return trip; the other commodity being hauled pays the freight in the opposite direction.

Shipment of recovered materials via rail has long been used for moving certain recyclable materials to domestic markets. To make rail hauling more competitive, however, several rail lines are creating tariffs expressly for shipping secondary materials. Along that same line, trade organizations like the Institute for Scrap Recycling Industries (ISRI) have asked Congress to consider deregulating the railroads with respect to the movement of recyclables.

Temporary shortages of overseas export containers creates a barrier to transporting recyclables overseas. Although exported scrap metals do not require the use of overseas containers, they are usually required for paper and other recyclables. A container shortage in 1990 and 1991 caused problems for export brokers. Ongoing monitoring is necessary to alleviate such shortages.

Local recycling program planners should try to understand and accommodate haulers' needs.

In terms of transportation networks, local recycling program planners can be most supportive by attempting to understand and accommodate haulers' needs. This means having recyclables ready to load on schedule (never keep a driver waiting), allowing pick-ups during non-business hours if necessary, and shipping only full loads of recyclables. Finally, considering the use of rail transport and backhauls will help strengthen the national transportation network.

Business Development

Three primary approaches to developing new markets for recyclables are generally associated with business development: (1) attracting an established recycling industry to locate a manufacturing facility, (2) encouraging existing local manufacturers to use or increase their use of recyclables, and (3) assisting local entrepreneurs with the start-up of small-scale manufacturing businesses. However, it is important to note that most legitimate businesses will not be attracted or encouraged by a supply of recyclables alone; they need to know that sufficient demand for their products exists to make their operation financially viable.

Most businesses want to know that sufficient demand for their products exists to make their operation financially viable.

The most traditional approach to recycling market and economic development has been to encourage large companies to locate a plant in a given region by providing incentives. This method has been used successfully to develop recycling markets in many areas of the United States. For instance, for years, paper and steel mills have solicited competitive requests from potential suppliers of recyclables when deciding to locate new facilities; large suppliers along the east and west coasts, such as the cities of Boston, New York, or San Diego, are often competitors for such facilities. However, as the number of communities in need of markets continues to grow, the number of large recycling industries capable of locating and building new facilities does not. This is evidenced by the fact that more recently announced industry expansions are adding capacity to existing facilities rather than locating new facilities.

Encouraging large companies to locate in a region by providing incentives is a traditional approach to recycling market development.

More recent business development concepts for encouraging market growth focus on establishing local "linkages." Linkage studies identify the flow of goods and services in a specified region. Conducting a linkage study is one of the first steps toward eventually encouraging existing industries to use recovered materials generated locally and to encourage new business start-ups to do the same. This market development concept also lends itself well to local economic development.

Local officials, economic development staff, and recycling program planners should cooperate to determine optimum local opportunities.

Opportunities for working with existing industries or entrepreneurs are unique to each location. In using this type of market-development strategy, it is important that local elected officials, economic development staff, and recycling program planners work together to determine the optimum local opportunities. In investigating the potential for local interindustry linkages, it is important that an accurate determination be made of the amounts and suppliers of raw feedstock consistently available to manufacturers. In addition, opportunities to include existing intermediate processors should be investigated. A study prepared by Gainer & Associates on behalf of the Arcata (California) Community Recycling Center provides a good model for determining linkages and assessing the feasibility of working with existing businesses or entrepreneurs.

Education Strategies

Education is one of the most vital components to help foster market development among the public and private sectors. Educational programs must involve every sector of the population, including government officials; industry representatives; collectors, haulers and processors of recyclables; and the general public.

Government officials responsible for setting solid waste policy at the local, state, and federal levels must be educated to understand the impact of policy decisions. Whether procurement of recycled products is mandatory or voluntary, government employees should be educated to pursue procurement practices favorable to recycled products whenever possible.

Education is vital to fostering market development between the public and private sectors.

Industry officials need to be made aware of the importance of recycling at their facilities and of using recycled products. Perhaps even more important, industry managers should be provided with information regarding local legislation, available supplies of recyclables, developing recycling technologies, and funding sources. Creating a working group including industry and government officials is an important mechanism to facilitate such information sharing. Some industry groups themselves have created education campaigns geared toward other population sectors. The Institute for Scrap Recycling Industries' "Design for Recycling" program, which promotes mandatory and voluntary efforts to assist recyclability of materials, especially metals, is one such noteworthy effort.

The collecting and processing sector is a vital link to market development, since it is through this sector that a reliable supply of quality recyclables is generated. Education programs geared toward helping collectors understand the importance of quality control at the curb or drop-off site are vital. Likewise, educating public- and private-sector processing facility employees is important to ensure that manufacturers' specifications will be met.

The public is another vital link to market development.

The general public may be one of the most vital links to market development, and educational programs for this sector are, therefore, of utmost importance. The public must be educated to understand the importance of participating in recycling programs and following local requirements regarding contaminants and acceptable materials. In addition, efforts must be made to increase public awareness of recycled products sold at retail outlets. Finally, information about standardized definitions for "recycled" products needs to be disseminated to the public so individuals can understand and assess the environmental and recycled claims made by manufacturers. "Buy Recycled" campaigns coordinated by state governments in Michigan and Minnesota have successfully promoted procurement of recycled products by the public.

To implement an effective local education program, it is useful to appoint an education committee to work with recycling staff or volunteers. Committee members should include representatives from local government, manufacturing industries, the commercial sector, recyclers (collectors / processors), and the public. The committee should devise a comprehensive local education strategy. The members will also educate the other members of their respective interest groups, for example, the Chamber of Commerce or the City Council.

Cooperative Marketing

Regional marketing cooperatives help maintain reliable markets and improve bargaining power.

To maintain more reliable markets and to improve bargaining power, communities around the country have formed regional marketing cooperatives. By identifying and negotiating with buyers, the cooperative acts as the agent for member communities. For example, in New Hampshire more than 100 small communities participate in the New Hampshire Resource Recovery Association cooperative marketing program, a nonprofit organization that provides marketing, technical, and education services. Such programs are also being initiated in upstate New York, Wisconsin, Minnesota, and Arizona, among other states.

The benefits of cooperative marketing include the ability to amass greater recyclable volumes for sale and economies of scale for processing and program administration. The challenges facing communities following a cooperative approach include maintaining quality control of recyclables collected by members, adopting an appropriate legal structure, and developing equitable means for sharing program costs and revenues. A marketing cooperative can be designed to have both public- and private-sector membership. Local recycling program planners wishing to investigate the feasibility of cooperative marketing can contact communities in their county, solid waste district, or region. Since planning commissions, nonprofit organizations and state recycling offices often track interest in such programs, contacting one of those agencies may also be useful. The National Cooperative Marketing Network has recently compiled data on cooperative marketing programs in the U.S. and Canada to help those interested in these programs.

ASSESSING AND CHOOSING COLLECTION AND PROCESSING TECHNOLOGIES

Choosing appropriate technologies requires making three preliminary decisions:

- *which methods to use for collecting recyclables*
- *how the collection system will operate*
- *what type of facility is needed for processing materials.*

After deciding what materials will be recycled and estimating the quantities of each, the community is ready to develop a basic program design. For most communities, developing a design will involve making three important decisions. First, the community must decide what collection method(s) to use. Second, the community must decide how the mechanics of the collection system will work. Third, the community must decide what type of processing and storage facility is needed to prepare materials for marketing. To develop a unified, efficient program, each decision must be made in relation to the others.

When analyzing available collection and processing arrangements, the interaction between the public and private sectors should be carefully considered. Even where public pickup of refuse is conducted, some communities are opting for private collection of recyclables. Private businesses are also providing waste processing services. A thorough analysis of potential collection and processing options should include an analysis of the benefits and costs associated with all public- and private-sector alternatives, including a combined approach. Of course, recycling collection and processing systems must be designed to incorporate state recycling legislation.

Ways to Collect Recyclables

Residential Waste Drop-Off and Buy-Back Collection

Deciding how recyclables will be collected is important.

At the outset, collection program developers must decide the best way for citizens, institutions, and businesses to prepare recyclables for collection and the best way to collect the materials. Local conditions should be taken into account when designing a collection program. For a small rural community that does not provide curbside pickup, educating and encouraging citizens to deliver materials to a drop-off site may be all that is needed. A recycling center can be established at the same location where residents deliver waste. Mobile recycling drop-off trailers can also be used. Drop-off recycling, however, is less convenient than curbside pickup. In order to promote high public participation, communities saving on the cost of collection by instituting a drop-off program must make special efforts at promoting the cost benefits of the reduced service to local residents. If a thorough educational and promotional effort is not made, drop-off programs tend to have lower participation rates than curbside collection.

Drop-off programs require thorough education and promotion to achieve participation rates similar to those of curbside collection.

Establishing a buy-back center (a place where recyclables are purchased) may help induce citizens to recycle. Some buy-back centers purchase some materials and accept others, depending on current market conditions. Private or public mobile buy-back operations can serve some areas of the country, purchasing recyclables in small communities or in neighborhoods of large metropolitan areas on a regular schedule.

Curbside Collection Options

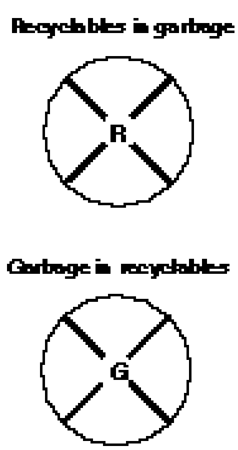
To maximize recyclable collection, many communities, large and small, are establishing curbside collection programs. There are a variety of approaches being tried; most are seeking the optimal balance among citizen and business participation and transport needs versus material processing requirements. Many communities provide both drop-off and curbside pick-up centers. Drop-off centers work well for items such as waste oil that are hard to pick up at the curb.

Source Separation

In source separated programs, recyclables picked up at curbside are kept separate from the waste.

Many communities now provide curbside pickup of recyclables kept separate from other waste. There are a variety of options used, depending on community resources and goals. Some communities are providing rigid and stable containers for collection of recyclables. Bins and buckets are most popular. Programs using bins and buckets have been very successful; the social pressure that results when neighbors can see who is and isn't complying with the program helps to spur high participation rates. Although using bins and buckets means higher initial cost for each community, many communities feel that the visibility of the program and the high participation rates make the investment worth it (see Table 6-9). Communities have experienced some problems with theft of bins and the materials they contain. Another approach uses plastic bags, with all recyclable materials placed in one bag and all nonrecyclables in another bag. Pick-up crews are instructed to leave at the curb any waste that is put in improper bags. They affix stickers (see Figure 6-2) to the bags indicating why they were not picked up. Because neighbors can see if a resident's waste has not been collected, compliance with such a program is generally high because of social pressure. Using plastic bags also allows existing collection equipment to be used, although care must be taken to ensure that the mixed recyclables do not contaminate one another (for example, broken glass contaminating plastic and paper).

Figure 6-2
Examples of Stickers Indicating Why Waste Was Not Picked Up



Source: Prairie du Sac, Wisconsin

For both bin and bag collection, issues of privacy have been raised. Some citizens have stated that it is an invasion of privacy to be forced to allow refuse collectors, or anyone walking by, to know the types of garbage that a resident generates. This type of opposition could cause problems for some communities.

Mixed-Waste Collection

This approach requires the least change in generators' habits. Communities collect waste unsorted as usual in one truck, and waste processing to remove recyclables is done later. This approach is obviously most convenient for resi-

Mixed-waste collection is convenient and requires few changes in habits and minimal education efforts.

But mixing refuse can contaminate otherwise recyclable materials.

dents and eliminates the need for most education. For some commodities, such as cardboard from food stores, so-called "dump and pick" operations have been successful. Because the cardboard makes up a large fraction of the total collected refuse and wastes that might otherwise contaminate it are absent, the cardboard remains relatively clean and easy to separate.

But mixing municipal refuse can result in contamination of waste that would otherwise be recyclable. Paper can become covered with wet food debris and glass can be broken. For some of the first mixed-waste processing facilities, upwards of 25 percent (by weight) of incoming recyclable material was contaminated and thus unmarketable.

However, because of the convenience for both citizens and collectors, many communities, especially large urban centers, are developing mixed-waste processing projects. Known also as full-stream processing, mixed-waste processing to remove recyclables is usually performed in conjunction with compost or refuse-derived fuel (RDF) production (see Table 6-10). Manual and mechanical separation to remove recyclables is performed at the front end of the process. Although the total volume of recyclables marketed from these facilities may be lower than the volume recovered when source separation is required at curbside, communities and businesses operating these plants point out that the total percentage of waste diverted from landfilling through production of RDF and compost is significant (see Table 6-11). Some of the

Table 6-9

Costs and Participation Rates by Container Type

	Blue Boxes	Stacking	Sacks	Buckets
Participation rates				
Average weekly set out rate (percent)(1)	56	42	36	40
Overall participation rate (percent)(2)	88	62	55	78
Average pounds per set out	14.40	18.46	13.94	16.47
Average pounds per week per household	8.11	7.90	5.09	6.69
Average number of set outs per household	6.42	6.16	6.24	5.18
Frequency of set outs per household (1 set out/# weeks)	1.40	1.46	1.44	1.74
Container handling time (seconds/set out)(3)				
Driver	23.52	24.17	26.78	25.00
Collector	32.39	15.78	31.65	22.04
Driver and collector average	27.95	19.97	29.21	23.52
Container costs(4)				
Capital cost per household	$5.50	$17.00	$0.86	$3.80
Capital cost for 38,000 homes	$209,000	$646,000	$32,680	$144,000
Approximate container lifetime(5)	10 years	5 years	1 year	3 years
Percent containers replaced annually(6)	5	5	100	5
Annual replacement cost	$10,450	$32,300	$32,680	$7,220
Annual amortization costs(7)	$34,014	$170,000	$ ——	$58,065
Total annual cost	$44,464	$202,713	$32,680	$65,285

(1) The average percentage of homes placing a set out on the curb in any given week.

(2) The percentage of homes participating at least twice during the nine-week study.

(3) Measured as the time from first touching the container(s), sorting the material into the truck bins, and replacing the container(s) on the ground. The highest and lowest of 25 measurements for driver and collector were dropped.

(4) These prices are offered for comparative purposes only and may vary due to the percentage of recycled plastic used, quantities ordered, and customization of the container. For current prices, contact the manufacturers directly.

(5) The lifetimes are based on manufacturers' claims and may vary with extremes of heat and cold, exposure to sunlight, and abuse of the containers.

(6) The 5 percent figure is based on the experience of many communities and accounts for loss and container theft, and people moving and taking their containers. The 100 percent figure in the Sack neighborhood includes the factors stated above and sacks wearing out.

(7) Amortization figures are based on a 10 percent annual interest rate.

Source: Gitlitz, J. 1989. "Curbside Collection containers: A Comparative Evaluation," *Resource Recycling* January/February

When considering mixed-waste processing, the experience and reputation of the technology vendor is important.

mixed-waste facilities process source-separated materials (see Table 6-10). New technologies are increasing recovery efficiency. When investigating the potential for mixed-waste processing, the experience and reputation of the technology vendor is a key consideration.

Wet/Dry Collection

In this variation of mixed-waste collection, wet materials—yard trimmings, food scraps, disposable diapers, soiled paper, and animal waste—are separated from other materials for collection. The wet stream is composted. Other materials, including recyclables, form the dry portion. Some communities collect all of their dry waste mixed and separate recyclables during processing. Others require further separation of dry materials into recyclable and nonrecyclable fractions. In Some programs require generators to bundle newsprint or take glass bottles to a drop-off site to reduce contamination and breakage. In this approach, a separate collection vehicle is usually used for each container type.

Combined Collection Options

Many communities provide a combination of drop-off, buy-back, and curbside collection. Often some collection is publicly provided, with other collection provided by local businesses. Especially in large communities, a combination of options may lead to higher participation and result in a more effective overall program.

Table 6-10

Selected Mixed Waste Processing Operations

	Delaware Reclamation	Fillmore County	Future Fuel	Rabanco	Recomp	Refuse Resource Recovery Systems	Reuter County	Sumter	Wastech	XL Disposal
Type of waste (1)	R-90%, C-10%, sludge	R, C	R, C	SC	R, C	R-80% C-20%	R	R-80%, C-20%	SC	R
Throughput (2) (tons/day)	1,000 (R,C), 260 (sludge)	8, also 3 SS	45	150-200, 100 SS	100	300-400 start-up, 600+ design	400	60	48, also 60 SS	376 start, 400 design
Recycled materials (3)	F, NF, G/M	ONP, F, P, NF, G/S	OCC, F, NF, P	OCC, MP, G/S, F, NF	OCC, F	ONP, OCC, MP, F, NF, P	OCC, F, NF, P	F, NF, P	OCC, MP, F, NF	ONP, OCC, F, NF, P
Products	Compost, pellets	Compost	Compost Pellets	None	Compost	Compost	Pellets	Compost	None	Grit/glass, Pellets in start-up
Source separation	None	Curbside, drop-offs, household hazardous waste	None	Curbside, drop-off, buy-back	Curbside, buy-back, drop-off, commer-cial	Bagged recyclables collected with garbage	Curbside	Pilot curbside	Curbside, drop-off, commer-cial	None

(1) R = mixed residential solid waste, C = mixed commercial solid waste with a paper-rich fraction, SC=selected commercial waste with a paper-rich fraction.

(2) SS = source-separated curbside materials are also processed by this facility but with a different processing line of equipment. Design capacities are shown for facilities operating less than a year.

(3) ONP = old newspapers, OCC = old corrugated containers, MP = mixed waste paper, F = ferrous, NF = non-ferrous, G/M = mixed color glass containers, G/S = color-sorted glass containers, P = container plastics (e.g. HDPE, PET).

Source: *Resource Recycling*, 1990; *1990-91 Materials Recovery and Recycling Yearbook*

Collection Schedule

Stating clearly how each citizen and business is to take part in the program is necessary.

Collection scheduling is another important consideration. Generally, programs that collect recyclables weekly on the same day as regular trash is picked up experience the highest participation rates. However, the same-day pickup may involve additional equipment and personnel; this may make same-day pickup beyond the economic resources of some communities. Decreasing the collection frequency may result in lower participation. Collection options are discussed in the next section.

Citizens must know what is expected of them. A clear statement by the community of how each citizen and business is to take part in the program is a necessity. This can be accomplished through the use of an ordinance. For communities that may experience theft of recyclables, a strong antiscavenging ordinance should also be considered. The structure for model ordinances is discussed in this chapter in the Ordinances section.

Business and Bulky Waste

Many businesses generate large volumes of recyclables — always consider this source when developing a program.

Many businesses generate large volumes of clean, homogeneous wastes. Highly effective recycling programs can be developed to collect these wastes from a variety of similar businesses on a routine basis. In many communities around the country, there are successful programs recovering these high-quality waste streams. Business and institutional recycling should be considered during program development. Different programs are described below.

Waste from Retail Businesses

Many consumer-oriented businesses, especially retail stores, produce large quantities of corrugated cardboard. If this material is kept separate from other waste streams, it is easily and economically recycled. However, cardboard must be sorted carefully because it can easily be contaminated with food

Table 6-11

Recovery Levels for Selected Mixed Waste Processing Operations

	Location	% Recyclable materials	% Other products (1)	% Landfilled
Delaware Reclamation	New Castle, DE	4	80	16
Fillmore County	Preston, MN	8	N.A.	N.A.
Future Fuel	Thief River Falls, MN	16	73	11
Rabanco	Seattle, WA	N.A.	N.A.	N.A.
Recomp	St. Cloud, MN	5	55	40
Refuse Resource Recovery Systems	Omaha, NE	(2)	(2)	(2)
Reuter (3)	Eden Prairie, MN	7	38	55
Sumter County	Sumterville, FL	7	76	17
Wastech	Portland, OR	50	0	50
XL Disposal	Crestwood, IL	14	20	66

N.A. = Not available.

(1) Such as refuse-derived fuel and compost.

(2) Refuse Resource Recovery Systems must recover, as recyclable materials or compost, 20 percent of the wastes delivered by the city, which represents 65 percent of the stated throughput. This diversion goal increases two percentage points per year until 30 percent is reached. A separate yard waste collection program will start in April 1991. Omaha estimated diversion in 1991 to be 44 percent.

(3) Two-thirds of the RDF is stored because Reuter has been unable to sell it.

Source: *Resource Recycling*, 1990; *1990-91 Materials Recovery and Recycling Yearbook* wastes. Weather (precipitation, wind, etc.) can also damage the quality of corrugated cardboard. Retail businesses also frequently produce large volumes of office paper, wood, glass, and plastic.

Waste from Restaurants and Bars

Bars and restaurants produce large quantities of glass and aluminum.

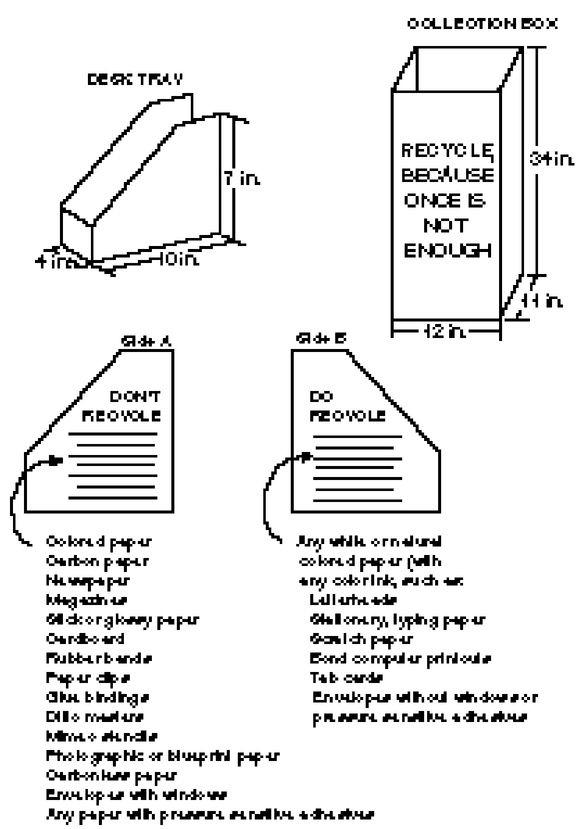
Bars and restaurants produce large quantities of glass and aluminum. Glass can become a storage and safety problem and its marketability can be affected by contamination. Metal tabs, for example, if mixed with glass, can significantly reduce the value of the glass. Glass should also be separated by color unless a processing center performs this task.

High staff turnovers in the bar and restaurant business can also create problems with ensuring that workers properly separate the materials. A continuing effort at working with cooperating businesses is necessary for glass recycling.

Many restaurants and grocery stores with butcher shops create a regular supply of used cooking oil, grease, and animal fat. These materials can be rendered into a variety of useful products, including animal feed, soap, lard, and cosmetics. Storing such materials must be carefully planned to avoid generating objectionable odors or attracting vermin.

Institutional Waste

Figure 6-3
Office Paper Recycling Containers



Source: The Resource Recovery Section, Waste Management Division, Michigan Department of Natural Resources

Government offices and businesses such as banks and insurance companies generate quantities of used paper, much of which is high quality, including tab cards, computer printout paper, and ledger paper. To successfully create a program to collect and recycle such paper, a system must be developed for bringing wastepaper normally generated by individuals a few pages at a time to a central location where the paper can be collected. Some systems make use of individual desk collecting bins, while others have central boxes or collection points.

Employee education is a key: workers must be told which types of office paper can or cannot be mixed together. Figure 6-3 shows an example of office paper recycling containers used by the Michigan Department of Natural Resources. Also, some effort must be made at predicting office paper volumes. Overflowing waste bins or boxes will create a potential for fire or accident, as well as opposition from those being asked to cooperate.

In addition to recycling office paper, many businesses want to shred corporate documents before disposal and will pay a premium to have documents rendered unreadable. Shredding requires an investment in processing equipment, but could prove economically attractive for recyclers working with proprietary businesses. The shredded material, properly segregated, can be recycled.

Wood and Construction/Demolition Material

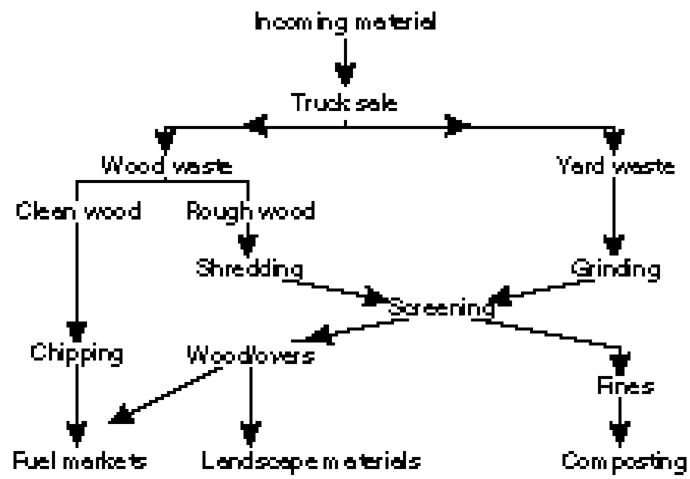
Contamination by dirt, metals, or masonry decreases the recyclability of wood.

Also avoid contamination from asbestos, PCBs, and other hazardous materials.

Wood recycling is on the rise. Many businesses generate pallets, which can either be repaired and reused, chipped into fuel or plant bedding material, or reconstructed into other secondary products. Demolition projects can also be a source of high quality wood wastes for recycling (see Figure 6-4).

Contamination by dirt, metals, or masonry can significantly decrease the recyclability of wood. Care must be taken to ensure that hazardous materials, such as asbestos and PCBs, do not become mixed with recovered items.

Figure 6-4
Material Flow Chart for Wood Waste Management



Source: Schroeder, R. 1990. "Operating a wood waste recycling facility," *BioCycle*, December

Appliances

Communities have recycled appliances (refrigerators, stoves, washers, dryers) for many years. Most provide for or require a separate pickup, and some charge generators for the special service. Appliances are delivered to metal scrap recyclers.

Some states require removal of PCBs, and federal law requires recovery of chlorofluorocarbons (CFCs) before appliances are recycled.

In recent years, scrap recyclers have become wary of shredding appliances that may have capacitors containing PCBs, a hazardous material. Although PCBs are no longer manufactured in the United States and only a small percentage of all appliances contain PCB capacitors, some scrap recyclers refuse to accept any appliances containing capacitors, and others are charging a per-appliance fee to pay for capacitor removal. The local market situation should be monitored so that the economics of appliance recycling can be accurately determined. Some states require removal of PCBs before recycling. Federal law requires recovery of chlorofluorocarbons (CFCs) before any appliance is recycled.

OPERATIONAL ISSUES

Collecting Recyclables

The next question that must be addressed is how to most efficiently move recyclable material from each generator to the processing facility. Depending on community resources and desires, this question, too, has a variety of answers (see Table 6-12). As previously stated, the choice of collection method(s) will influence how the entire collection system will operate.

Either public or private collectors can be used.

An initial decision is who should collect recyclables for the community. One approach is to use existing public sanitation workers. Another is to use public workers for collection of waste and contract with private haulers for collection of recyclables. Many private haulers now offer full-service collection. The level of recyclable collection service which will be provided to the commercial and institutional sector should be determined and clearly communicated, so that these entities can make alternative arrangements if necessary.

Recycling collection is sometimes subject to public bidding, with the winning bidder receiving a contract for the entire community.

For first-time collection programs in large cities served by private haulers, the number of haulers is a key consideration. In some communities, recyclable collection is subject to public bidding, with the winning bidder receiving a contract for the entire community. This procedure can be administratively efficient for the community, but can displace smaller haulers already serving the community who may be unable to bid on a large contract.

Other communities have opted to allow existing trash haulers the opportunity to also provide recycling collection services to the neighborhoods and businesses they serve. This procedure protects existing small haulers, but it must be closely monitored to ensure that all haulers follow program guidelines and are actually recycling the materials collected. Some communities require haulers to obtain permits and to file reports showing participation rates and volumes collected.

Table 6-12
Collection Characteristics

Community	Frequency	Same Day as Trash	Provide Container	Household Separation	How
Barrington, IL	Weekly	No	Yes	Three	P-M-G
Blaine, MN	Weekly	Yes	Yes	Three	P-M-G
Boulder, CO	Weekly	65%	Yes[1]	Three	P-M-G
Champaign, IL	Weekly	No	Yes	N/S	N/A
East Greenwich, RI	Weekly	Yes	Yes	Two	P-C
East Providence, RI	Weekly	Yes	Yes	Two	P-C
Franklin, PA	Monthly	Yes	Yes	Three	P-M-G
Irvine, CA	Weekly	Yes	Yes	Three	P-M/Pl-G
Ithaca, NY	Weekly	Yes	No	Separate	I.M.
Jersey City, NJ	Weekly	No	No	Two	P-C
Lafayette, LA	Weekly	Yes	Yes	Three	P-M-G/Pl
New London, CT	Weekly	Yes	Yes	Two	P-C
Olympia, WA	Weekly	Yes	Yes	Three	P-MP-C
Ontario, CA	Weekly	Yes	Yes	Four	P-M-G-Pl
Orlando, FL	Weekly	Yes	Yes	Two	P-C
Oyster Bay, NY	Weekly	No	Yes	Two	P-C
Saint Louis Park, MN	Weekly	Yes	Yes	Three	P-M-G
Seattle (North), WA	Weekly	Partial	Yes	Three	P-MP-C
Seattle (South), WA	Monthly	No	Yes	One	All
Shakopee, MN	Weekly	Yes	Yes	Three	P-M-G
Trenton, NJ	Bi-Monthly	No	Yes	Two	P-C
Whitehall Twp, PA	Weekly[2]	60%	Yes	Three	P-M-G

P — Paper; M — Metal; G — Glass; Pl — Plastics; C — Mixed Containers;
MP — Mixed Paper (Separate); I.M. — Individual Materials

1. Container for newspaper only.
2. Newspaper collected one week, containers collected the next.

Source: Glenn, J., "Curbside Recycling Reaches 40 Million," *BioCycle*, July 1990

Structure private collection programs to avoid anti-competition claims from competing firms.

Regardless of whether one private hauler or a variety of private haulers are used, the program should be carefully structured to avoid claims that the program violates anti-competition laws. A hauling business that loses customers or one that is unable to gain new customers may blame the community for illegally restricting business opportunities. The attorney serving the community should be consulted to develop proper bidding and permit procedures.

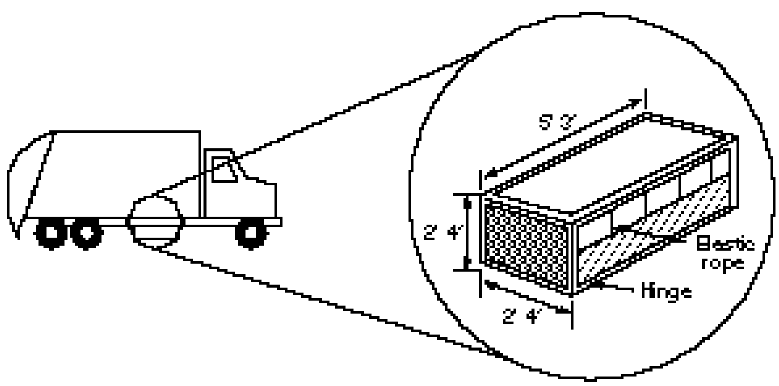
Collecting Residential and Commercial Waste

In the initial planning stages, communities usually have two choices: they can use existing equipment to collect recyclables, or they can invest in new equipment. Private haulers have the same options and often ask a community to help finance new equipment purchases. Many communities begin with existing equipment and expand the program to include more specialized vehicles when the program has had some operating experience.

For programs starting up, existing community or private equipment, such as refuse collection trucks, pickup trucks, and dump trucks, is often used to collect recyclables. Refuse trucks can be converted to allow paper collection (see Figure 6-5). Using existing equipment saves money at the outset, but can be inefficient if recyclables cannot be kept separated. In addition, existing equipment may present a hazard to workers, who may be forced to lift recyclable containers high in the air to drop materials into a dump truck or pickup truck without a lift gate. Attaching a trailer to an existing dump truck to collect both recyclables and waste together may work. However, this technique has caused problems in communities with alleys and cul-de-sacs, which make turning difficult for long collector vehicles. Some haulers are collecting separated, bagged recyclables along with other bagged waste in the same truck.

Figure 6-5

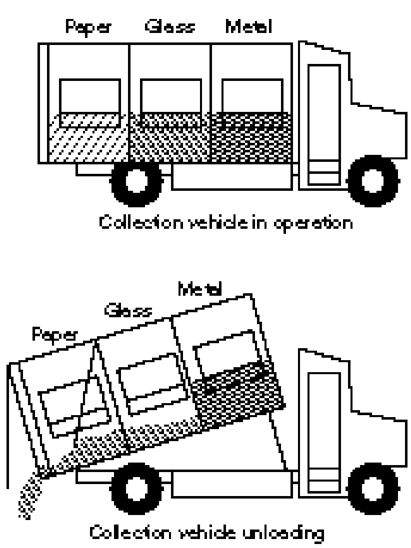
Newspaper Rack for Rear-Loading Collection Vehicle



Source: Adapted from City of Madison

Figure 6-6

Source Separation Collection Truck



Source: P. O'Leary & P. Walsh. University of Wisc.–Extension, Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles 1988

Increasingly, compartmentalized vehicles to transport and keep recyclables separate are being developed (see Figure 6-6). These trucks are low to the ground and allow workers to keep a variety of recyclables separated in the truck. Where communities use bin systems, vehicles with two or more compartments are usually used for collection. Collection personnel may take longer to collect material at each residence because they must throw separated material into each compartment. However, the contamination rates for these collection schemes are lower and processing time at the processing facility may be shorter.

Selecting trucks with compartments must be done carefully; it is very important to consider the ratio of the volume of different commodities to be collected. Ignoring or miscalculating the ratios can result in costly expenditures of time and fuel. Prematurely filling one compartment will force a truck off its route to off load materials. Off loading a truck filled to only 1/4 or 1/2 of its capacity dramatically increases labor costs and overall fuel consumption. Recyclable collection trucks are now available with movable partitions, allowing adjustments based on space needs.

Special Collection Problems

Many large urban communities choose to collect waste commingled from multi-family dwellings and inner city areas.

Obtaining high participation rates and quality control for recycling programs has been a problem in both multi-family dwellings and in inner-city urban neighborhoods. Some speculate that high resident turnover in these housing areas results in less understanding of the requirements of the source separation program. Others feel that neither multi-family nor inner-city dwellers share the sense of responsibility for community well being that spurs residential families to recycle. Whatever the reason, a number of large urban centers have given up on requiring multi-family dwelling and urban source separation and have chosen to collect such waste commingled, even if other areas of the city practice source separation. This approach requires different processing (sometimes different processing facilities) for each type of collection.

Other communities feel that special efforts at improving education, monitoring, convenience, and motivation are needed. Information, including newsletters, flyers, or posters, is provided on a regular basis, perhaps monthly. The program is personally explained to new tenants or neighborhood residents. At multi-family dwellings, managers or caretakers provide active oversight to ensure compliance and quality control. In urban areas, a block captain or neighborhood recycling committee may fulfill the role of educator and motivator.

Residential and commercial waste recycling programs are designed with convenience in mind. Recycling containers are placed in areas convenient for both residents and haulers (for example, basements may be avoided because they can be dirty and may attract vermin). Each container is well marked and can be reached by children. Pickup is regular, to help alleviate storage problems that can make recycling difficult for apartment dwellers. Fire codes may also affect storage options.

Siting processing centers in urban areas and hiring local residents can help link recycling with local economic benefits.

Motivating people in multi-family dwellings and the inner-city is also necessary. Some success has been achieved by establishing buy-back centers in inner-city areas to spur economic interest in recycling, especially among children. Some suggest that siting processing centers in urban areas and hiring local residents are crucial to linking recycling with local economic benefits. Providing some portion of recyclable sales revenue to a neighborhood group or a tenants' association may also provide a valuable economic incentive to improve participation and quality control, although these economic incentives must be balanced against the increase in program costs, which may have to be borne by other parts of the community.

PROCESSING/STORAGE CENTER DESIGN

How waste is collected helps determine the processing/storage facility design.

Collected recyclables are normally delivered to a processing facility, where the recyclables are either stored until large enough volumes are collected to be marketable or are processed to meet the specifications of recycling markets. Obviously, the manner in which waste is collected will help to determine the processing/storage facility design.

Small communities or groups of communities may develop small drop-off centers that feed a larger processing facility (see Figure 6-7). The drop-off center/large processing facility approach provides each small community with the benefits of a convenient, low-cost collection point, as well as the economies of scale and higher volumes that a large processing facility can provide. Each drop-off center can be serviced by a transporter on a regular basis, or transporters can be called when the center has reached capacity. Who pays for recycling transportation and how the material should be transported must be decided.

To manage large urban recycling programs, many communities consider implementing MRFs, which are designed to process large volumes of recyclable material in the most efficient and cost-effective manner; some can handle thousands of tons of material and many types of recyclables.

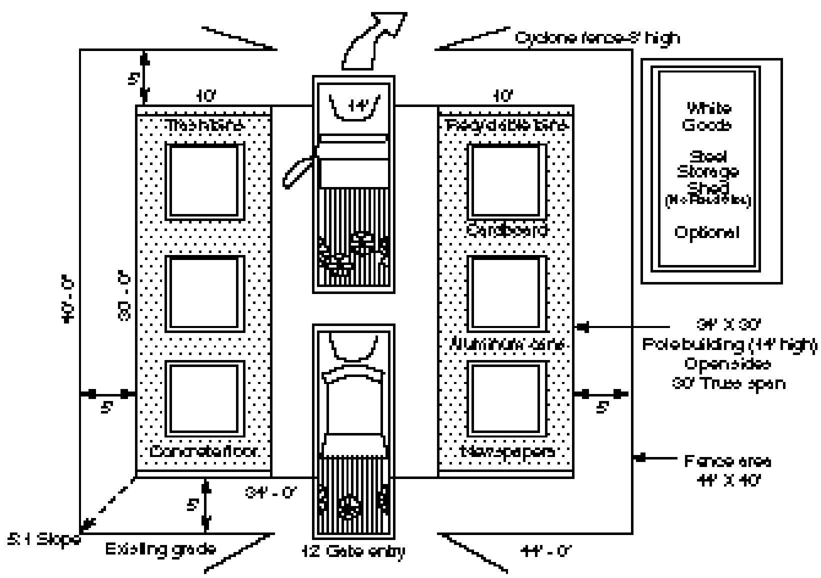
MRFs should be designed to receive, sort, process, and store recyclable material efficiently and safely.

The design goal for a MRF is to receive, sort, process, and store recyclable material efficiently and safely. Although most recyclable material will be trucked to the facility, some facilities provide for citizen drop off or buy back. Depending on whether materials are delivered to the facility as mixed waste, mixed recyclables, or separated recyclables, there are a variety of options and tradeoffs involving equipment and personnel.

There are three major issues that must be addressed when building and designing a MRF. First, a site must be found that can accommodate the building and its associated features for traffic and storage, and be consistent with local land use. Second, the building layout and equipment must be designed to accommodate efficient and safe materials processing, movement, and storage, in compliance with local building codes. Third, the building must be designed to allow efficient and safe external access and to accommodate internal flow. Each of these design issues is discussed below and special considerations are highlighted.

Figure 6-7

Rural Container Station



Source: Northwest Wisconsin Regional Planning Commission

Site Location

The ideal MRF location is a large piece of clear, uncontaminated land in an industrial area close to the source of material production.

The ideal location for a MRF is a large piece of clear, uncontaminated land close to the source of material production and located in an industrial area. Industrial areas normally have access to utility services and to different modes of transportation, including rail, barge, and highway. Moreover, neighbors are accustomed to the volume of truck traffic that would be received by a recycling center. Also, noise associated with operation of processing and storage equipment at the recycling center should not create the type of problems that a center located in a more residential area may create. A site in an industrial area would also be properly zoned, which would obviate the need to seek rezoning or a variance as part of the site approval process. Finding and obtaining such an ideal site could be extremely expensive or even impossible for many communities.

Manufacturing sites must be evaluated for possible hazardous materials/waste problems.

Communities can consider various options, such as locally owned government property or used industrial property (warehouses, manufacturing facilities, etc.). However, if a site has been used for manufacturing, be sure that no hazardous waste or hazardous material problems exist at the site. Leaking underground storage tanks, crumbling asbestos insulation, or contaminated soil could turn a low-cost piece of property into a fiscal nightmare. Performing an environmental audit before acquiring the property is recommended. If a large enough property with a building is available, an investigation should determine if the building can be retrofitted to house the recycling facility or if it should be razed. More details on siting a facility can be found in Chapter 2.

Area

The site must be large enough to accommodate the recycling building, safe and efficient traffic flow for several vehicles, and have buffer space for fencing, landscaping, signs, and other incidentals (see Figure 6-8). If possible, entrances and exits for trucks should separate from those used by automobiles. There should be enough room for tractor / trailers of 55 feet and over to park and turn safely and easily. Also consider outdoor storage needs for revetments, pallets, baled materials, or appliances (see Figure 6-9). If possible, include an area for expansion.

Review local land use regulations to determine if setback regulations exist.

Local land use regulations should be consulted to determine if setback regulations exist. Likewise, some space should be set aside for fencing, signs, and landscaping. Adding trees or shrubs to the site design can provide a buffer zone, cut down on noise, and provide an aesthetically pleasing appearance to neighbors and to citizens using the site's drop-off center.

Scale

The site should have a scale that can be used to weigh both incoming and outgoing materials. Typical scale lengths are from 60 to 70 feet. The site should also accommodate a queuing area for trucks from the entrance to the scale and from the scale to the recycling facility. To determine the queuing area, some predictions must be made of the peak vehicle traffic times, as well as the time necessary to weigh and unload an incoming vehicle. Try to minimize the number of intersections and amount of cross traffic in the site design (see Figure 6-10).

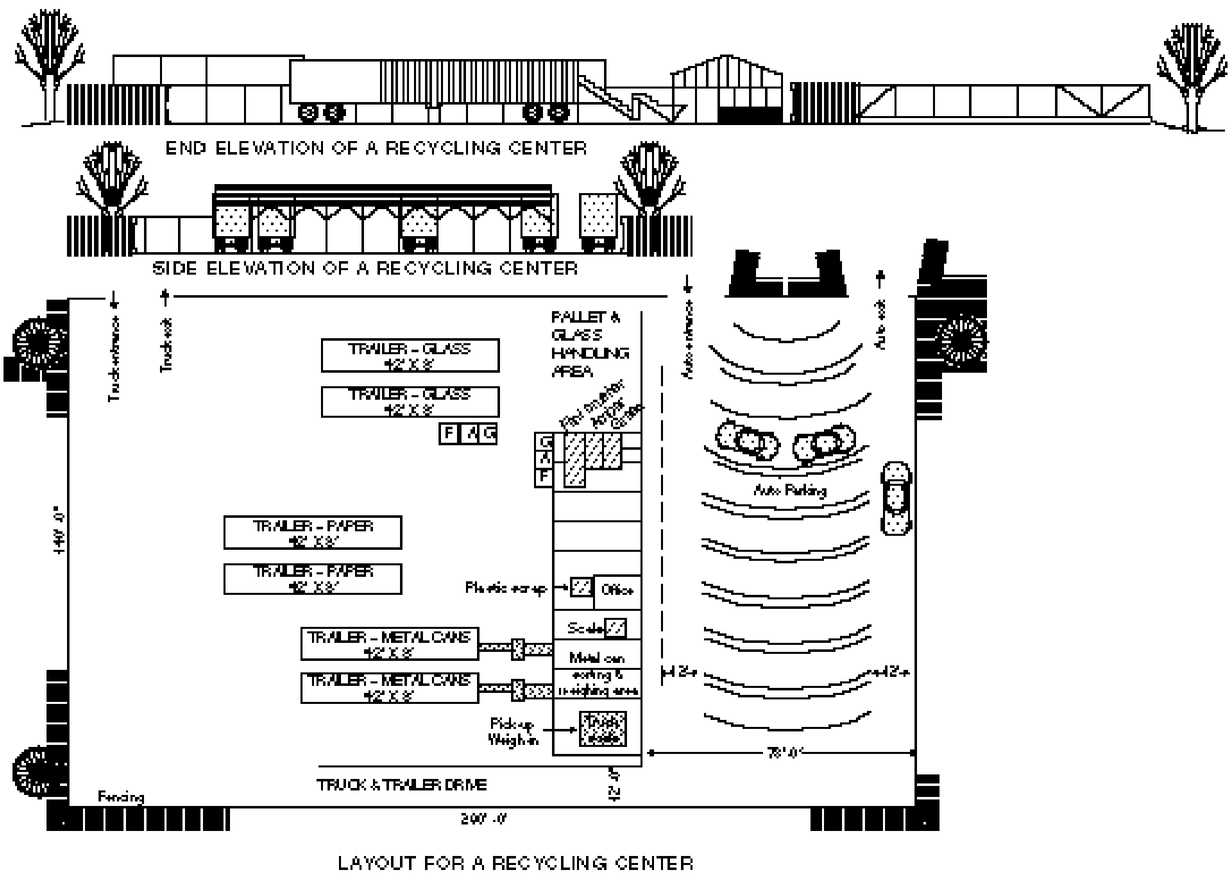
Building Design: Outside-Inside Interface

The facility's outside walls should be designed to allow safe and easy access for incoming and outgoing vehicles. It is important to design doors wide and high enough to accommodate vehicles unloading inside the building. Door damage has been a problem at many MRFs because of collisions caused by empty, but still open, trucks backing out. There should be enough doors to accommodate the expected number of trucks at normal peak times. The same is true for areas where materials will be loaded onto trailers for transport to markets.

Tipping or Unloading Area

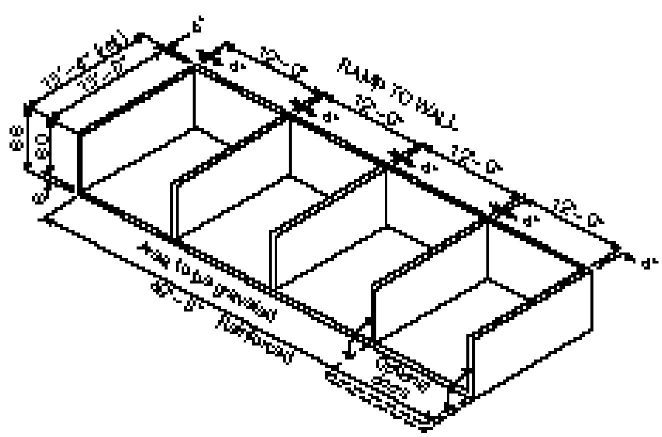
The tipping or unloading area should be designed to accommodate at least two days' expected volume of material, although even more space would be preferable because insufficient area to handle incoming waste is a common

Figure 6-8
Recycling Center, Toledo, Ohio



Source: *The Complete Guide to Planning, Building and Operating a Multi-Material Theme Center*, Glass Packaging Institute, 1984

Figure 6-9
Recycling Revetments



Source: Manitowoc County, Wisconsin Ad Hoc Committee on Recycling problem for MRFs. The tipping floor can be unheated, but the design should ensure that cold air does not infiltrate the processing area.

Larger MRFs often accept both source-separated and commingled materials.

Larger MRFs are usually expected to accept both source-separated and commingled materials. Although all recyclable material could be accommodated on one large tipping floor, designing the facility with separate areas for separated and commingled recyclables may be best. This facilitates more efficient processing in the building, since processing equipment may be different for each. Signs should clearly indicate to each driver the proper location for material delivery.

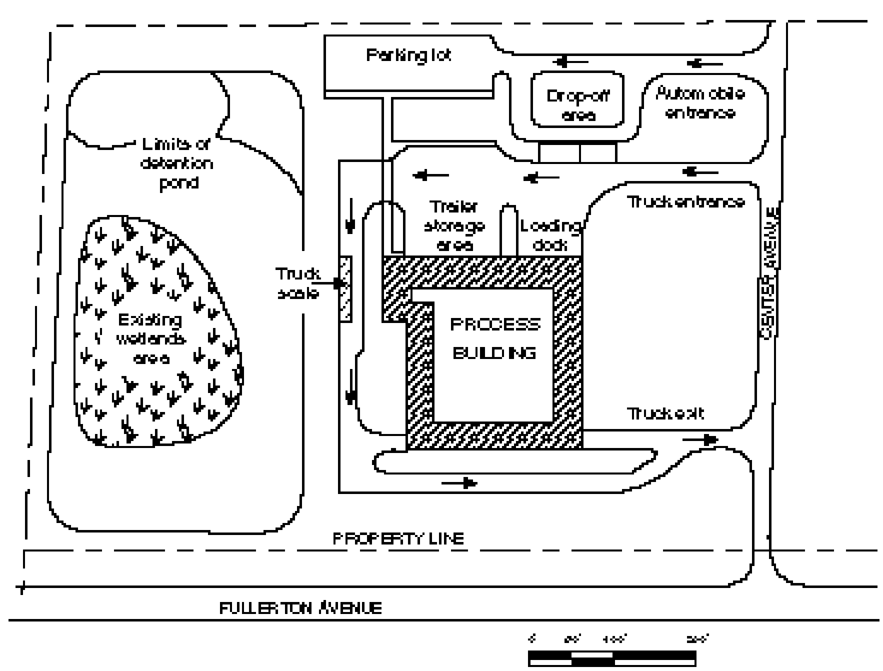
A MRF can be designed to run more than one shift. With this option, sufficient storage space on the tipping floor is essential to allow for processing during the second shift. One approach is to process all separated material during the first shift and all commingled material during the second shift. Using multiple shifts may allow for an overall smaller facility design, although the tipping floor may need to be larger.

The tipping or unloading floor should be designed to handle heavy weights, withstand the wear caused by pushing and moving recyclables, and to provide efficient drainage for liquids brought in by trucks. Wet floors pose safety hazards for employees and create difficult working conditions. The design must also minimize glass breakage, which poses safety hazards and creates a large percentage of nonrecyclable volume at many MRFs. If possible, use a sloped tipping pit or ramp to minimize jarring. Corrugated cardboard can also be placed on the tipping floor as a cushion. Reducing the number of times each load must be handled also reduces breakage.

The area needed for the tipping or unloading floor can be estimated by using the material characterization data collected and converting the anticipated recyclable weights to loose volumes (see Table 6-13). Remember to account for slopes at the ends of stored material piles. By adding up the expected daily volumes of the commodities to be processed, the daily throughput for the facility can be estimated.

Figure 6-10

Material Recycling Facility Site Plan and Traffic Flow, DuPage County, Illinois
North Intermediate Processing Facility



Source: Camp Dresser and McKee, Inc. 1991

Table 6-13

Sample Weight to Volume Conversion Factors for Recyclables

Material	Volume	Weight in pounds
Newsprint, loose	one cubic yard	360-800
Newsprint, compacted	one cubic yard	720-1,000
Newsprint	12" stack	35
Glass, whole bottles	one cubic yard	600-1,000
Glass, semi crushed	one cubic yard	1,000-1,800
Glass, crushed (mechanically)	one cubic yard	800-2,700
Glass, whole bottles	one full grocery bag	16
Glass, uncrushed to manually broken	55 gallon drum	125-500
PET, soda bottles, whole, loose	one cubic yard	30-40
PET, soda bottles, whole, loose	gaylord	40-53
PET, soda bottles, baled	30" x 62"	500
PET, soda bottles, granulated	gaylord	700-750
PET, soda bottles, granulated	semi-load	30,000
Film, baled	30" x 42" x 48"	1,100
Film, baled	semi-load	44,000
HPDE (dairy only), whole, loose	one cubic yard	24
HPDE (dairy only), baled	32" x 60"	400-500
HPDE (mixed), baled	32" x 60"	900
HPDE (mixed), granulated	gaylord	800-1,000
HPDE (mixed), granulated	semi-load	42,000
Mixed PET and dairy, whole, loose	one cubic yard	average 32
Mixed PET, dairy and other rigid, whole, loose	one cubic yard	average 38
Mixed rigid, no film or dairy, whole, loose	one cubic yard	average 49
Mixed rigid, no film, granulated	gaylord	500-1,000
Mixed rigid and film, densified by mixed plastic mold technology	one cubic foot	average 60
Aluminum cans, whole	one cubic yard	50-74
Aluminum cans, flattened	one cubic yard	250
Aluminum cans	one full grocery bag	1.5
Aluminum cans	one large plastic grocery bag	300-500
Ferrous cans, whole	one cubic yard	150
Ferrous cans, flattened	one cubic yard	850
Corrugated cardboard, loose	one cubic yard	300
Corrugated cardboard, baled	one cubic yard	1,000-1,200
Leaves, uncompacted	one cubic yard	250-500
Leaves, compacted	one cubic yard	320-450
Leaves, vacuumed	one cubic yard	350
Wood chips	one cubic yard	500
Grass clippings	one cubic yard	400-1,500
Used motor oil	one gallon	7
Tire — passenger car	one	12
Tire — truck	one	60
Food waste, solid and liquid fats	55 gallon drum	412

Source: *DRAFT National Recycling Coalition Measurement Standards and Reporting Guidelines,* presented to the NRC Membership, (October 31, 1989)

Storage Area

Table 6-13 can be used to estimate storage needs.

Table 6-13 can be used to estimate storage needs. After determining the types of equipment that will be used to process and compact the recyclables, a general estimate can be made of space requirements to store this material. It is important not to underestimate storage space needs. Enough storage space should be available to store materials for sufficient periods to gain high-volume prices or to account for the inability to sell some materials during market downturns. Some materials can be stored outside or in trailers, depending on market specifications.

Building Structure

The building should have as few interior columns as possible. This will allow the maximum flexibility for placing equipment and accommodating future needs to rearrange the layout. The floor should be strong enough in all places to accommodate both vehicles and heavy, stationary processing equipment. The floor should also be designed to allow for anchoring equipment. Although there may be a need to design in some recyclable pits to hold various materials, keeping a flat floor space will allow for easier moving or changing of equipment.

The ceiling should also be high enough to accommodate equipment specifications. Especially for larger MRFs, conveying lines, air classifiers, shredders, and other processing equipment can be as tall as forty feet. For flexibility, it is just as important to have enough space vertically as horizontally (see Figure 6-11).

Employee and Education Facilities

Locker rooms, bathrooms, showers, a first aid station, an administrative office, a weighing station and public education facilities should be considered.

In addition to estimating space for material drop off, processing, and storage, the design must include space for employee facilities. Locker rooms, bathrooms, showers, a first aid station, an administrative office, and a weighing station should all be considered. For facilities that operate a buy-back center along with the MRF, space for a cashier and an area for accepting recyclables from the public should be provided. Large facilities often have rooms where the operation can be explained to public tour groups or for use as a lunch room. The rooms have windows overlooking the processing floor, and educational programs can be conducted safely and quietly.

Depending on the site's geographic location, radiant heating units or space for furnace or air conditioning equipment should be part of the design. Local building codes should be consulted to determine work place minimum environmental standards. If employees are to be drawn from a specialized work force, such as developmentally disabled individuals or the handicapped, special regulations may apply. A shop for housing tools and maintaining equipment could also be part of the design.

Hazardous Materials Area

MRFs accepting household hazardous waste or waste oil should include a special area designed according to local, state, and federal requirements.

A MRF may or may not be designed to accept household hazardous waste or waste oil. If the MRF is intended to accept household hazardous waste or waste oil, a special area should be designed according to local, state, and federal requirements. Even if household or other forms of hazardous waste will not be accepted as part of the recycling program, some area should be set aside for storing the hazardous materials that will no doubt be received at some time during the MRF operation. Hazardous waste, medical waste, low-level radioactive waste, and other hazardous chemicals may be found in incoming loads. A protocol for handling this material should be established.

Employees should be carefully trained to reduce risk of injury or exposure. Accepting hazardous waste can complicate siting and permitting requirements.

Building Layout and Equipment Choices: Manpower Versus Machines

Manual sorting yields high-quality, low-contamination loads of recyclables and minimizes downtime.

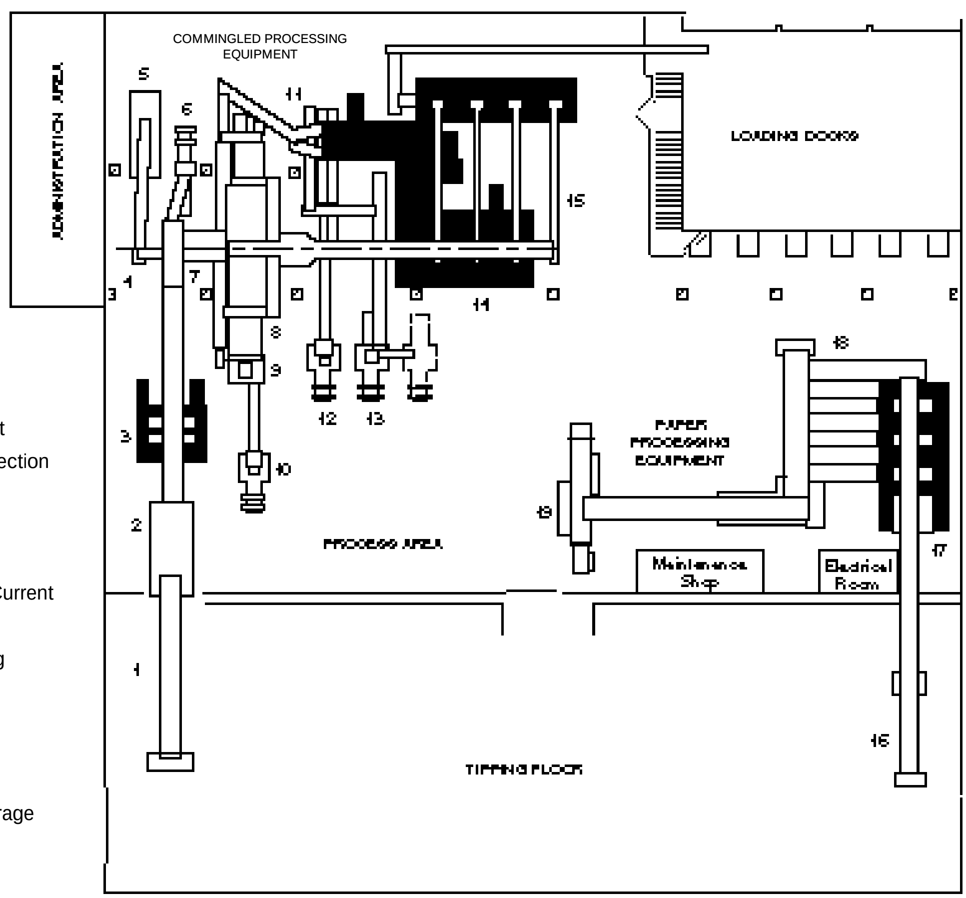
Manual sorting is the best way to get high-quality, low-contamination loads of recyclables and experience less downtime. For some commodities, such as mixed colored glass, manual sorting is the only proven feasible alternative. However, manual sorting can also be dirty, dusty, dangerous, and expensive, especially when large volumes of material must be handled.

Mechanized sorting equipment providing improved handling efficiency at an acceptable quality is available.

Increasingly, mechanized sorting equipment is becoming available, which may provide improved handling efficiency at an acceptable quality. This equipment is designed to receive commingled recyclables and separate the total volume into its component parts, such as aluminum cans, plastics, glass, and ferrous metals. Classifiers, using air or mechanical methods, separate light materials from heavier. Eddy currents separate aluminum cans. Magnetic belts or drums can pick off ferrous metals. Proprietary technology,

Figure 6-11

Facility Layout, DuPage County, Illinois, North Intermediate Processing Facility



1. Commingled Infeed Pit
2. Flow Control Sensors
3. Pre-Sort Station
4. Overhead Electromagnet
5. Reject and Residue Collection
6. Ferrous Baler
7. Vibrating Screen
8. Inclined Sorting Table
9. Vibrating Screen/Eddy Current
10. Aluminum Baler
11. Head-on Plastics Sorting Stations
12. PET Plastics Baler
13. HDPE Plastics Baler
14. Glass Sorting Station
15. Glass Crushers and Storage Bunkers
16. Paper Infeed Pit
17. Paper Sorting Station
18. Paper Storage Bunkers
19. Paper Baler

Source: Camp Dresser and McKee, Inc. 1991 such as the BRINI system, is available. New techniques include the Bezner system, which uses moving chain curtains to trap light materials like plastic and aluminum cans, while allowing denser materials, such as glass, to move through the hanging chains. Optical scanners are also being developed to sort glass by color. More technology for sorting recyclables is expected to come on the market in the near future.

Several factors affect the decision to use manual or mechanical sorting methods.

In designing a MRF, decisions about whether to rely on manual sorting or mechanical sorting must be based on the volume and types of materials to be handled; the economics of purchasing, operating, and maintaining the equipment versus the cost of hiring additional employees; and market requirements concerning the degree of acceptable contamination. High-volume facilities should probably be designed to use mechanical sorting if efficient equipment is available, supplemented with manual sorting for quality control (see Figure 6-12). A primary design goal should be minimizing the number of times that material must be handled as it moves through the facility.

Conveyor Line

Handling efficiency for a MRF is greatly enhanced by using conveyor lines to move waste from the tipping area through processing. Conveyor lines can be used merely for transporting materials to mechanical equipment or can act as moving lines that allow workers to separate various commodities. Conveyor lines are an integral part of any well-designed MRF.

A conveyor line should be designed to allow an employee to be standing upright or seated while separating materials. If an employee must bend over or stand in an uncomfortable position, injuries will result. Likewise, the line should be designed to keep employees from snagging clothes or receiving injuries while sorting. Emergency shut-off cords and palm-size panic buttons should be included with conveyor systems.

To achieve very low contamination levels, a positive sorting system should be used.

If very low contamination levels will be accepted by markets, a positive sorting system should be used. In positive sorting, recyclables are picked from the conveyor and placed in storage containers; with negative sorting, contaminants are picked off the conveyor, but everything else ends up in the same storage bin. Negative sorting allows a greater percentage of contaminants to slip through the process.

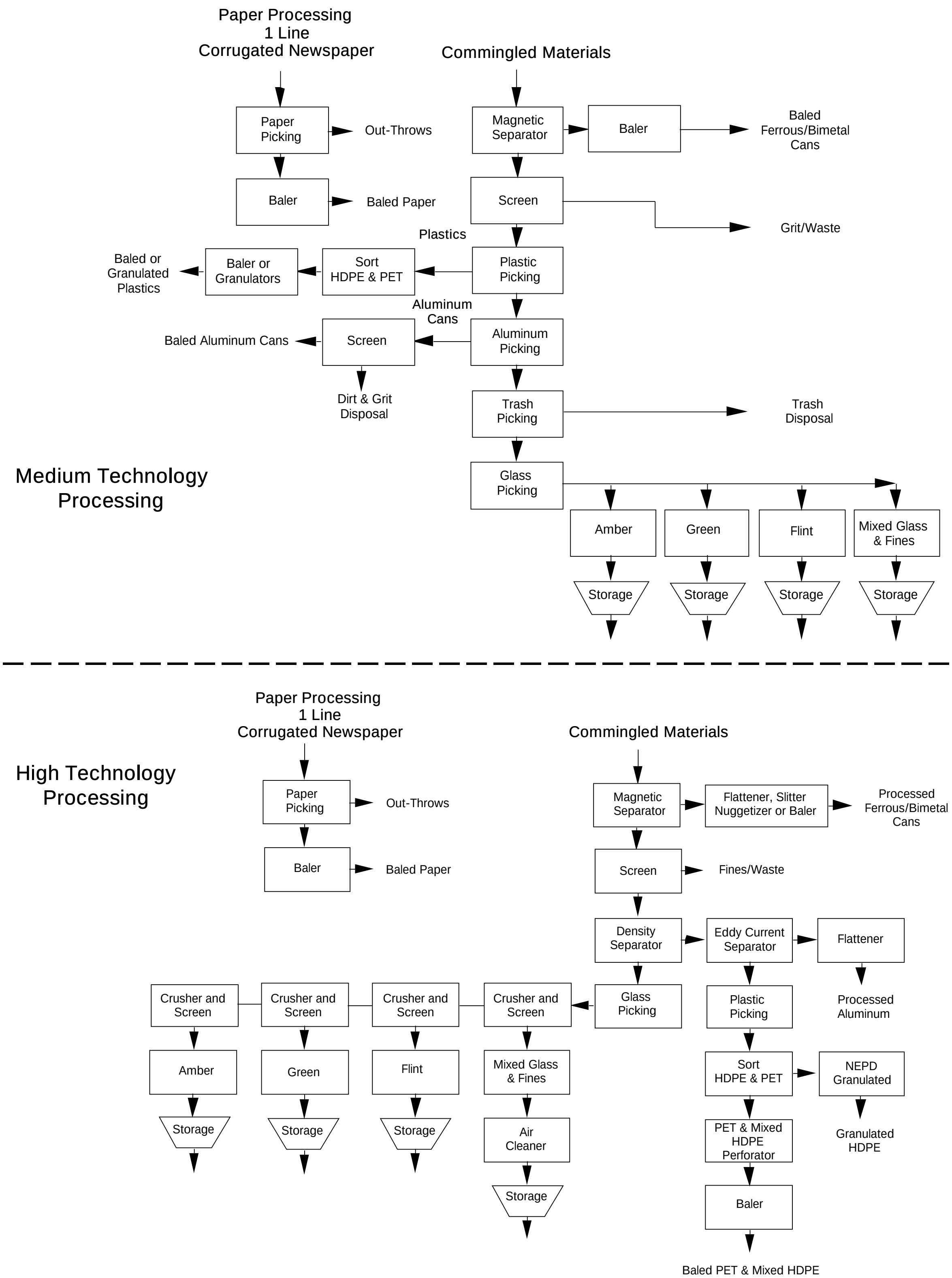
Processing and Densifying Equipment

Decisions about buying processing equipment depend on the volume of material and market requirements.

For small operations, collected recyclables can be stored loose in Gaylord boxes and marketed directly. The feasibility of this option depends on local markets and transportation costs. Most recycling centers use some processing and densification equipment in order to increase the price paid by a market or to lower unit transportation costs by maximizing the volume in each load. Decisions about buying processing equipment depend on the volume of material that will be handled and especially on the requirements of the markets. Some markets want to receive material baled, some shredded, others loose. Some markets will accept waste in a variety of forms, but will pay different prices for each. Processing equipment should be selected carefully for each facility to meet its particular processing requirements. The capital and operating costs, along with space requirements, must be balanced against the improved marketability and revenue that processing will bring.

Balers are usually the most versatile piece of processing equipment that recycling centers use. Balers can be used to densify many types of materials including paper, cardboard, plastic, and cans. Using a baler facilitates stacking bales, which improves space utilization and reduces material transportation costs. Balers come in a variety of sizes and prices. For industrial markets, large bales (600-1200 pounds, 30-40 inches wide) are the norm. For animal bedding from newsprint, small bales, on the order of 70 pounds each, are preferred by farmers.

Figure 6-12
Medium and High Technology Processing



Source: Pferdehirt, W. "Planning Bigger, Faster, More Flexible MRFs," *Solid Waste and Power,* October 1990

Higher-volume facilities typically require balers with continuous-feed (rather than batch) capability, and with an automatic tying mechanism. Larger processing facilities typically have one heavy-duty baler for all paper materials and one or more medium-duty baler for cans and plastics. A baler to be used for PET bottles can be fitted with a perforator, thereby eliminating the need to manually remove caps from the bottles before baling. Balers for paper materials should be equipped with a swing-out ruffler that can be engaged when baling newspapers to increase bale density.

Glass crushing improves densification and makes for more cost-efficient loads.

Glass crushing improves densification and makes for more cost-efficient loads. Glass-crushing equipment can be as simple as a sledge hammer used to crush glass through a hole in the top of a 55 gallon drum of glass. A hammer mill can also be used, if large volumes must be crushed. Some recycling operations simply drop glass from the top of a long conveyer onto other glass piled in a revetment, using gravity as the breaking force. Equipment to crush, screen, and store glass must be designed to accommodate the highly abrasive nature of crushed glass; well-designed glass processing equipment often includes wear plates that can be routinely replaced. Marketing requirements, volume needs, and resources will help determine which type of glass-crushing equipment is feasible.

The market will determine whether a shredder is needed or, in the case of plastics, acceptable.

Shredders and chippers can be used for newsprint (for animal bedding), mixed paper, plastic bottles, and confidential documents. The market will determine whether a shredder is needed or, in the case of plastics, acceptable. Shredders and chippers should be equipped with safety protections, including dust control.

Other specialty equipment like can flatteners can also provide improved densification. Frequently in the past, processing equipment that was developed for other uses was converted and used for recycling. Recently, industry has begun developing processing and densification equipment especially for recycling operations. Improvements in equipment design and operation are expected in the future.

Handling Equipment

Even small recycling operations will need some methods of moving materials from the tipping area to storage and from storage to transport vehicles. When 55 gallon drums are used, hand trucks or dollies may be sufficient. However, for 55 gallon drums of glass, handling with a hand truck can be dangerous and difficult.

The MRF layout should allow sufficient aisle space for efficient and safe movement of materials.

For larger operations, fork-lift trucks to move baled material are a must. Front-end loaders are also used to move loose materials such as paper, glass, and cans. For air quality purposes, propane or electric fork-lift models should be used inside. Diesel or gas models are fine for outside work.

In developing the layout for the MRF, it is important to allow sufficient aisle space for efficient and safe movement of materials. Handling equipment must have sufficient room to move from processing to storage areas, preferably without the need to make tight turns or to cross flow paths used for moving other materials. The traffic pattern should also allow for rapid loading and unloading of vehicles.

When choosing processing, handling, and densification equipment, it is important to consider equipment life cycle costs.

When making decisions about processing, handling, and densification equipment, it is important to consider the life cycle cost for this equipment. In addition, factors such as the capacity of the machine, whether it is continuous feed or batch feed, its reliability record or servicing needs, and energy requirements are all important. Likewise, the space needed for equipment and the required loading and unloading areas should be noted. Also, reinforced concrete slabs should be designed to withstand the weight of loaded collection trucks and tractor trailers and to properly support equipment and stored materials.

Redundancy

Including redundancy in equipment processing capability is important.

When laying out the overall design of the MRF and making equipment choices, it is important to include redundancy in equipment processing capability where possible. Equipment failure in one area of the MRF should not cause the entire operation to shut down. Although cost and space requirements may prevent having two of everything, developing multiple sorting lines and alternative handling methods will make the system less prone to shut down. Likewise, equipment should be placed so that both routine and special maintenance can be performed easily and without disruption to other MRF functions. Having an operator from an existing MRF on the new facility's design team can help avoid future operational problems.

DEVELOPING AN ORGANIZATIONAL PLAN AND BUDGET

To be successful, recycling operations must be run like businesses.

Whether the recycling operation is public or private, to be successful it must be run like a business. In the past, many community programs were run with mostly volunteer labor. Although some volunteers may still be used, successful recycling programs rely on trained personnel and have an institutionalized structure within the community. The program must be designed to run smoothly despite changing conditions and personnel turnover.

Organization

Recycling programs can be designed to be purely public, public and private, or purely private. The legal organization of the recycling program will depend on local circumstances and the desire for allocating risk and control. Special attention should be given to legal requirements in deciding on the program organization.

Recycling programs can be designed to be purely public, public and private, or purely private.

For a purely public program, the operation could be run by the public works department and overseen by the city council or county board. For multijurisdictional programs, a sanitary district or recycling commission could be formed, depending on local laws. For these operations, intergovernmental agreements stating clearly the duties and responsibilities of each municipal member should be signed. A system for sharing expenses and revenues, an enforcement policy, and other programmatic details should be clearly stated.

For private programs, a decision needs to be made whether the operation should be for profit or nonprofit. Nonprofit corporations are tax exempt, but have greater government scrutiny of financial operations. Deciding whether to become a for-profit or nonprofit corporation is a major decision that should be discussed thoroughly with a qualified attorney.

Regardless of the legal structure, the organization should have clear delineation of responsibility.

Regardless of the legal structure, the organization should have clear delineation of responsibility. For any recycling program to succeed over the long term, someone must be directly responsible for ensuring that the program is properly managed. Without this clear responsibility, inefficiencies will develop, maintenance will be ignored, education and promotion efforts will slip, and downturns in the market could threaten the program's viability.

A recycling program will not run itself. For any large program, a paid manager or staff is necessary. The staff should have broad business and organizational skills. Personnel must have the ability to operate and supervise use of a variety of expensive and often dangerous machines. The manager should also be an effective promoter of the recycling program; he or she must be able to conduct public education and awareness programs and work with the local press. Other support personnel—office workers, cashiers, bookkeepers, accountants, and maintenance and cleaning personnel—should be planned as part of the organization. Paying a fair wage is crucial to attracting and keeping qualified employees.

Budget

The budget should estimate as accurately as possible personnel, equipment, building, and other expenses.

Using the information developed in the previous steps, a detailed budgetary breakdown should be prepared. The budget should estimate as accurately as possible personnel, equipment, building, and other expenses. It should indicate anticipated capital and operating costs for a MRF or a collection center and predict revenues and other income sources. Because recycling markets are volatile, revenues from recyclable sales should be conservatively estimated. Budgets should include any program-related expenses, such as the cost of publicity and promotion, insurance, utilities, office equipment, and maintenance (see Table 6-14). The availability of state and local grants or loans should also be considered.

When several scenarios are considered, a budget should be prepared for each. For example, a large community might compare building one very large MRF versus two or three smaller ones. Establishing transfer points to move smaller quantities of material to a central MRF can also be considered. Likewise, purchasing a costly piece of processing equipment can be compared to costs for additional manual processing without the equipment. While cost is not the driving force behind most recycling programs, comparing costs and discussing goals can help a community choose from a variety of options.

Financing

Revenue from selling recyclables is usually inadequate to cover all program costs.

Most communities budget additional tax moneys or develop alternative financing strategies.

Revenue from the sale of recyclables is usually inadequate to cover all program costs. Most communities need to budget additional tax moneys or develop alternative strategies for program financing. Some also use program financing methods as incentives to recycle, for example, charging for waste collection on a volume-based standard. Such "user-fee" or "generator-pay" systems internalize the cost of waste production for each generator, thereby encouraging them to decrease the amount of waste they discard by changing buying habits, reusing materials, and increasing recycling. To encourage recycling, recyclable collection is often provided free or at low rates and its costs rolled into the nonrecyclable rate base. These programs have improved recycling rates and decreased overall waste volumes.

In some rural communities, an increase in littering or home disposal has occurred when a volume-based system was instituted. In urban areas, residential waste may be dumped in commercial dumpsters. Additional education and publicity may be necessary to explain program benefits when such problems develop.

Many private haulers will work with communities to share the benefits and risks of recycling. Some haulers provide a rebate to communities based on the volume of recyclables collected and the volume of waste diverted from the landfill. Careful negotiations during contracting can provide a strong incentive for both the hauler and the community to work hard to make recycling a success. A contract that shares benefits and risks should also provide a procedure for sharing costs during slow market periods.

Communities owning a landfill, MRF, waste-to-energy plant, compost operation, or transfer station may be able to help underwrite recycling program costs by including within its tipping fee a portion for recycling. Private haulers and other communities would then be supporting community recycling efforts. The tipping fee increase can also be seen as an incentive to recycle.

ADDRESSING LEGAL SITING ISSUES

Addressing legal issues during the planning and implementation stage is crucial.

A variety of legal issues must be addressed in developing an effective recycling program. Resolving these issues as part of the planning and implementation process is crucial. Forgetting or ignoring a legal requirement could stop the entire program in its tracks because of a legal challenge. To keep program

A detailed budgetary breakdown including all program-related expenses should be prepared.

Table 6-14: Model Budget

Budget Categories:

- Personnel
- Equipment
- Supplies
- Contractual
- Leasehold and site improvement
- Other operating expenses
- Space rental

Budget Categories	Total	Donated
Personnel		
Salary and fringes	$00,000	
Overtime	0,000	
Subtotal	$00,000	
Equipment		
Floor scale	$0,000	$0,000
Portable scales (2)	0,000	0,000
Truck, hydraulic lift tailgate	0,000	0,000
PET grinder	00,000	
Forklift Truck		0,000
Can crushers	00,000	0,000
Aluminum and steel sorter	0,000	
3 chain-flail glass crushers	0,000	
Belt conveyor	0,000	0,000
Wooden steps (paper trailer)	000	
Self-dumping hoppers	0,000	0,000
Bulk cullet containers		0,000
Push carts (10)	0,000	0,000
Pallets (50)		000
Miscellaneous signs	0,000	
Glass storage bins	0,000	
Subtotal	$000,000	$00,000
Office Equipment		
Cash register	$0,000	
Furniture	0,000	$0,000
Typewriter	000	
Calculator		000
Phone answering machine	000	
Subtotal	$0,000	$0,000
Supplies	$000	$000
Contractual		
Professional fees	$0,000	
Physical plant layout and design		$0,000
Subtotal	$0,000	$0,000
Leasehold and site improvements		
Grading and paving	$00,000	$00,000
Building construction		00, 000
Outside lighting		0, 000
120/140 volt power		0,000
460 volt power		0,000
Subtotal	$00,000	$00,000
Other Operating Expenses		
Utilities	$0,000	
Advertising	0,000	
Repairs and maintenance	0,000	
Trash and snow removal	000	
Insurance	000	
Phone	000	
Gas and oil	00	
Other	000	
Subtotal	$0,000	
Space Rental	$0,000	
Grand Total	$000,000	$00,000

Source: *The Complete Guide to Planning, Building and Operating a Multi-Material Recycling Theme Center*, Glass Packaging Institute, 1984 development on schedule then, attention to legal issues is crucial. Some legal issues may result from legislative mandates at the state level.

Zoning and Land Use Considerations in Siting

When possible, it is best to look for a site already zoned for recycling processing.

A proposal to site a MRF may be opposed by neighbors. When possible, it is best to look for a site already zoned to allow recycling processing. If the best site available needs a zoning change or a variance, procedures to obtain the approvals should be initiated immediately. Some opponents may try to convince local officials that a recycling operation is a glorified junk or scrap yard. It will be important to show clearly that this is not the case.

As discussed in Chapters 1 and 2, plans for public involvement during program development should be implemented. By providing for public education and input, issues that could create opposition can be recognized and resolved. Public support for the community planning effort will be fostered. A well-conceived public involvement program will assist decision makers in generating a broad consensus in favor of the proposed community approach to recycling.

Building Codes

Follow local building codes carefully.

Local building codes should be carefully followed when designing a MRF. Basics such as the number of bathrooms, minimal working space per employee, and other requirements may be specified. Working condition rules such as minimum and maximum temperatures, air changes, and required ventilation may also influence design. Note that the standards may be higher if developmentally disabled workers will be employed.

Permits

All permits should be obtained before beginning the recycling program operation.

All necessary permits should be obtained before beginning the recycling program operation. Contact regulatory authorities to determine if permits are needed for air and water quality or solid and hazardous waste storage. Permits may also be needed for both intrastate and interstate transportation of recyclables, especially for overweight loads. Local governments may also have a variety of operating permits and other restrictions. Federal and state rules regarding employee and community right to know and employee safety should be studied. Protocols for meeting these criteria and protecting employees from injury should be established.

Contracts

Depending on the type of program, a variety of contracts may be needed. All aspects of recyclable operation, including collection, processing, and marketing, may be covered by contract. Construction of a MRF may also be covered by local bidding laws, and it may be necessary to negotiate a variety of contracts. Specifications for equipment purchases must also be developed.

General Business Regulation

Procedures for insurance, worker's compensation, tax withholding, and social security should be developed.

Procedures for business operation, such as adequate insurance, worker's compensation, tax withholding, and social security should be developed. If the operation of a public recycling program involves unionized employees, union contracts should be investigated to determine if problems could arise. This is an important consideration. Some cities have signed expensive contracts with private haulers only to find that the contracts violated union agreements. Special attention should be given to insurance, labor, and other issues in programs that will use volunteer help.

Ordinances

As part of a recycling program, a variety of ordinances may be needed. If mandatory recycling is chosen by state or local government, some programs may require local government enforcement to induce broad compliance. To ensure that people understand what is required of them, many communities use recycling ordinances that have the force of law.

While there is no all-encompassing model for a source recycling ordinance, in general each ordinance should have the following components:

In general, ordinances should have these components.

1. **Statement of purpose:** reasons recycling is being imposed, such as saving landfill space or protecting the environment.
2. **Applicability of the ordinance:** who must separate the waste? Does the ordinance apply to both citizens and private businesses? How will apartment houses be handled? Is anyone exempt?
3. **Items that must be separated:** not all communities want to recycle the same items. A definition section in the ordinance may be advisable to clarify which items must be recycled. Also, state which items—such as grass clippings or leaves—will not be accepted.
4. **Material processing:** processing requirements, such as crushing, cleaning, cap removal, bundling, or stacking in bins, should be clearly stated.
5. **Collection procedure:** some communities have separate pick-up days for recyclables and nonrecyclables. Others require drop off at recycling centers. The local situation will dictate how this is handled. For a recycling center, the hours of operation should normally be included in the ordinance.
6. **Penalties: s**ome communities impose fines for noncompliance. Others will not pick up unseparated waste.

It may be a good idea to enact an antiscavenging ordinance, too, in communities that will impose curbside pickup. The ordinance would make it unlawful for unauthorized persons to pick up recyclables from curbside. Fines for scavenging should be large enough to act as a deterrent. If a community's sole aim is to reduce the waste stream, scavenging may not be considered a problem. However, if program revenue is important, efforts at discouraging scavenging should probably be undertaken.

DEVELOPING A START-UP APPROACH

A recycling program involves a major change in handling waste for most citizens. A curbside collection program may require of a community large expenditures for new equipment and personnel. For recycling programs to be successful, citizens must know what is expected of them and must help make the program a success. If a program gets off to a poor start because collection is inconvenient or inefficient for local citizens, the long-term program may never achieve the success desired.

Expect unusually large amounts of recyclables for the first week or two weeks of collection. Citizens and businesses tend to save recyclables in anticipation of the beginning of the program. If not anticipated, this initial response can inundate collection vehicles and the MRF. Collections could slow and residents may be unhappy. Asking residents to set out recyclables over a number of collection days will help avoid problems. This request should be made during preprogram educational and publicity efforts.

Most programs benefit from devising and following a careful start-up plan.

Therefore, even with a well-designed program, a careful start-up plan should be devised. Although some communities successfully go from no recycling to mandatory curbside recycling, a better approach may be to devise a smaller scale or less compulsory start-up approach. The approach can be used to develop information that will help the community make decisions about how best to collect material and about which type of collection strategy works the best. Once the program is running at full scale, it may be difficult to make changes. Using a pilot start-up approach allows the community to try a number of ideas prior to making full-scale, expensive, and perhaps irreversible decisions. Phasing in the system, starting with the residences, then adding apartments and then businesses, has also been successful for some communities.

Pilot Programs

In pilot programs, recyclables are collected through a specific period using prescribed methods. The efficiency of the approach is then evaluated.

In a pilot program, recyclables are collected using prescribed methods for a certain period of time. The efficiency of the approach is then evaluated. Often, pilots are run using different methods in different neighborhoods so that results can be compared.

A pilot program serves a variety of needs. First, it allows the community to try an approach, such as clear bag collection or bin collection, without the expense of going community wide. Second, if coupled with a strong education and publicity program, the pilot program can begin public discussion and understanding of the recycling program and generate community support for source separation. Third, the pilot can provide a good estimate of the quantity of recyclables that can be expected. This information can be used to refine adjustments made earlier as part of waste characterization. Some communities have conducted pilot studies in place of waste characterization, feeling that an actual recycling program will yield better estimates of expected volumes than statistical studies.

The structure of the pilot can be fitted to the needs of the community. In a large city, a recycling program could be instituted in a few neighborhoods at first; eventually, the program could be extended to the whole city. Recycling could also be conducted only at a specific type of residence, such as single family homes, with the expectation that harder to reach citizenry, such as multi-family dwellers, would be added later.

Voluntary Recycling

Beginning programs with voluntary recycling may be beneficial, even for communities planning for mandatory recycling.

Beginning the program with voluntary recycling may be a good idea, even for communities in which mandatory recycling is anticipated. A voluntary program can be used to educate people concerning the requirements and benefits of recycling without the coercive enforcement of a mandatory recycling ordinance. Once citizens are used to the voluntary program and many are already participating, a shift from voluntary to mandatory will not seem such a large step. Changes in procedures can also be made more easily when the program is voluntary than when enforcement is associated with noncompliance. If a curbside program is being developed, voluntary drop-off centers can provide an option for those who are separating recyclables. The drop-off centers can also provide publicity for recycling in the community.

For many communities, the high participation rates achieved with a well-run and well-publicized voluntary program have eliminated the need for a mandatory program. Since it is always better for community well-being to seek cooperation rather than require it, an effort at voluntary source separation should probably be made at the outset. If a voluntary program does not achieve high participation rates, the local government then has a good political reason to move toward a mandatory program.

Communities can provide strong economic incentives to recycle by internalizing the cost of waste generation.

Another approach is to provide a strong economic incentive to recycle by "internalizing the cost of waste generation"—making recycling pay at the lowest level, for the user. For example, some communities charge variable rates for collecting recyclables and nonrecyclable waste, with the rate for recyclable collection being lower or free. This system provides a strong incentive to reduce overall waste costs by reducing waste generation and encouraging recycling.

In addition, many communities now charge for pickups of special items, such as white goods, tires, or furniture, which in the past were picked up as part of refuse collection. Along with encouraging recycling, these efforts at internalizing the costs of waste generation have also encouraged waste reduction at the source.

Mandatory Recycling

Among the various mandatory recycling programs now underway in the United States, each involves a different degree of community and citizen involvement. Curbside pickup is the most common type of mandatory source separation program. There is an important difference between a voluntary curbside pickup program and one that is mandatory. In many mandatory programs a resident who has not set recyclables out separately will not have his or her trash picked up. Many programs use stickers to indicate why waste was left at the curb (see Figure 6-2). Some mandatory programs impose fines for noncompliance, but to achieve compliance, most programs rely on the social pressure of having neighbors see that one's garbage was not picked up.

Curbside pickup is the most common type of mandatory source separation program.

In rural areas and for some types of waste in urban areas, ordinances require residents to take materials to drop-off centers. Some rural communities have recycling centers at their landfills, with bins for recyclables.

Mandatory drop-off programs appear to work best when an attendant ensures that people dropping off waste have first separated recyclables. In urban areas where mandatory drop-off is used, it usually applies only to yard trimmings which are composted at a central site.

Ten states and a number of communities in the United States have deposit legislation for beverage containers. Generally, states with deposit legislation recover more of the targeted material than states using other collection schemes. New beverage container deposit legislation is now highly controversial. Some recyclers are concerned that a beverage deposit system may disrupt the many curbside collection programs as valuable materials, such as aluminum, are diverted from the curbside program. However, many communities with beverage container deposit laws also have successful curbside collection. Some states have enacted deposit legislation for pesticide containers and auto and other batteries to keep these products from going into landfills.

Some state recycling laws and communities that operate landfills serving other municipalities have recently imposed source separation as a prerequisite for using the landfill. Fellow municipalities are required to enact recycling programs or look elsewhere for a disposal site. Waste that arrives at the landfill unseparated is rejected.

Some state recycling laws and communities that operate landfills serving other municipalities require source separation as a prerequisite for using the landfill.

Note that this approach places a heavier burden on the waste hauler. Problems with compliance are especially difficult for haulers who serve sources like apartment complexes, where separation is hard to enforce. For these programs, haulers and client municipalities need to work closely together to develop an effective program.

IMPLEMENTING THE EDUCATION AND PUBLICITY PROGRAM

Long-term success will be achieved by a recycling program only if the reasons for participating are understood and accepted by the public. The public and local officials must be regularly reminded of the environmental, economic, and social reasons for reducing the amount of wastes taken to a landfill. They should receive regular feedback concerning amounts recovered and participation. To accomplish this, a plan must be developed—and implemented—providing publicity and promotion on a routine basis.

How can recycling be promoted? Some communities have Boy Scouts and Girl Scouts deliver flyers to local residences. Others have included pro-

Programs achieve long-term success if the public understands and accepts the reasons for participating.

Accomplishing this requires a plan for providing publicity and promotion on a routine basis.

motional literature with water bills, tax bills, or weekly shoppers. Many have prepared public service announcements for radio and TV, and some have used special promotions. However, special promotions should be carefully considered, because some programs have experienced significantly decreased participation when the promotions ended.

Many citizens and businesses will have questions about new programs. A phone-in customer information service will smooth program implementation. Surveying community attitudes or conducting focus group sessions can also help determine which educational approach will work best.

Developing a recycling logo, which is placed on all community recyclable collection vehicles, is an effective method of publicizing the program. Recycling vehicles will be routinely seen by community residents during collection. The vehicles can also be used for publicity at public events such as fairs or sports competitions.

Education is the key to a recycling program's long-term success.

Although publicity and promotion are important ongoing needs, education is the key to long-term success. Children, who will one day be adults, will help determine whether recycling will become established, stable, and widely practiced in this country in the future. A number of curricula for teaching children about the need to recycle are now available. Children learn, through exercises specially designed for their grade level, how waste is produced, how much each person generates, where the waste goes, the environmental problems that can develop, and the benefits of limiting disposal needs through prevention recycling.

Besides educating the children, these programs often educate their parents. Many otherwise reluctant parents will participate if their children enlist their interest. While changing school curricula to include recycling education may take some time, a recycling program's chance of long-term success will be greatly enhanced if local educators become involved.

Plans should include a long-term schedule for promotion and education. Many recycling programs start with high participation rates during the first few months, only to see operations fail in the end because community outreach and education programs were neglected. The promotion plan should include periodic reports to local government officials concerning how the program is progressing. Local officials who are kept informed will be more amenable to providing both financial and legislative support for the program, should that become necessary.

BEGINNING PROGRAM OPERATION

If the program has been carefully planned and developed, program implementation should run smoothly. However, with new personnel, new equipment, and new rules for citizens, some problems will certainly develop. With patience and perseverance, the program can be fine tuned during its initial shakedown phase to make it run smoothly and efficiently. If the program is managed by an experienced recycling coordinator, the learning curve should be relatively short. A pilot program can help work the bugs out of a new system before the program is instituted throughout the community.

CONTINUING SUPERVISION, LONG-TERM PUBLICITY AND EDUCATION

Programs should be carefully supervised to maintain citizen and local government support.

Especially for a large community, a recycling program will be a significant investment of community resources. Recycling programs often start with great fanfare but are quickly forgotten as other community problems are faced. Unless the program is carefully supervised, citizen support could wane and problems could develop. Likewise, continuing local government support, such as for maintenance for the MRF, could decrease.

The key to long-term success for the program will be planning and education. An operational plan should provide for timely maintenance and replacement of equipment and for continuing publicity. Program expansion, new technology, and variable markets must all be expected and planned for. Both management and operating personnel must be willing to change and improve skills to keep ahead of new developments in the field.

Likewise, changes in the processing technology that will affect the collection program must be communicated to the public. For example, if a commodity that was not collected before is now collected, the public should be adequately informed. Periodically, "how to" literature should be redistributed to educate new residents and to reinforce program parameters to the community. If a former requirement, such as removing the label from a steel can, is no longer required, the public should be informed. A well-developed program will generate community pride as well as keep the program from encountering unnecessary contamination.

A program to inform local officials about program benefits and costs should be implemented.

A program should also be implemented to keep local officials informed about program benefits and costs. If future expenditures by the community are needed, the program will have the support base necessary to explain the requirements and generate political support for budget requests. It will be hard to convince an uninformed governing body that additional equipment or operating moneys will be needed for a recycling program.

REVIEWING AND REVISING PROGRAMS TO MEET CHANGING NEEDS

All programs should be constantly reviewed and adjustments made when necessary.

Even managers of successful programs must constantly review their programs' progress and make necessary adjustments. Recycling is a fast-moving field with new technology, fluctuating market conditions, changing consumer waste generation patterns, and changing regulations as federal and state environmental legislation is enacted. An effective program must be flexible enough to adapt as conditions change.

REFERENCES

Gitlitz, J. 1989. "Curbside Collection Containers: A Comparative Evaluation," *Resource Recycling* January/February.

Glass Packaging Institute. 1984. *The Complete Guide to Planning, Building and Operating a Multi-Material Theme Center.*

Glenn, J. 1990. "Curbside Recycling Reaches 40 Million," *BioCycle*. July.

Gorino, R. J. 1992. "Commodity Wrap Up," *Scrap Processing.*

National Recycling Coalition. 1989. *National Recycling Coalition Measurement Standards and Reporting Guidelines: Draft.*

Pferdehirt, W. 1990. "Planning Bigger, Faster, More Flexible MRFs," *Solid Waste and Power*, October.

Powell, J. 1993. "How Are We Doing? The 1992 Report," *Resource Recycling,* April.

Schroeder, R. 1990. "Operating a Wood Waste Recycling Facility," *BioCycle*. December.

Steuteville, R., N. Goldstein and K. Grotz. 1993. "The State of Garbage in the America," *BioCycle*. June.

USEPA. 1992. *Characterization of Municipal Solid Waste in the United States, 1992 Update*. EPA/30-R-92-019. July.

USEPA. 1990. *Procurement Guidelines for Government Agencies*. EPA/530-SW-91-011. December.

7 ❖

COMPOSTING

Composting involves the aerobic biological decomposition of organic materials to produce a stable humus-like product (see Figure 7-1). Biodegradation is a natural, ongoing biological process that is a common occurrence in both human-made and natural environments.

Composting is one component in USEPA's hierarchy of integrated solid waste management, which is discussed in the introduction to this guidebook (see Figure I-1 in the introduction). Source reduction tops the hierarchy of management options, with recycling as the next preferred option. Grasscycling and backyard composting are forms of source reduction or waste prevention because the materials are completely diverted from the disposal facilities and require no municipal management or transportation. Community yard trimmings composting programs, source-separated organics composting, and mixed MSW composting are considered forms of recycling.

It is important to view compost feedstock as a usable product, *not* as waste requiring disposal. When developing and promoting a composting program and when marketing the resulting compost, program planners and managers should stress that the composting process is an environmentally sound and beneficial means of recycling organic materials, *not* a means of waste disposal.

This chapter provides information about methods and programs for composting yard trimmings (leaves, grass clippings, brush, and tree prunings) or the compostable portion of mixed solid waste (MSW), including yard trimmings, food scraps, scrap paper products, and other decomposable organics.

From: Decision Maker's Guide to Solid Waste Management, Volume II, (EPA 530-R-95-023), 1995. Project Co-Directors: Philip R. O'Leary and Patrick W. Walsh, Solid and Hazardous Waste Education Center, University of Wisconsin-Madison/Extension. This document was supported in part by the Office of Solid Waste (5306), Municipal and Industrial Solid Waste Division, U.S. Environmental Protection Agency under grant number CX-817119-01. The material in this document has been subject to Agency technical and policy review and approved for publication as an EPA report. Mention of trade names, products, or services does not convey, and should not be interpreted as conveying, official EPA approval, endorsement, or recommendation.

7 HIGHLIGHTS

Composting is an environmentally sound recycling method. (p. 7-8)	Composting involves the aerobic biological decomposition of organic materials to produce a stable humus-like product. Compost feedstock should be viewed as a usable product, *not* as waste requiring disposal. Program planners should stress that the composting process is an environmentally sound and beneficial means of recycling organic materials, *not* a means of waste disposal.
Composting can significantly reduce waste stream volume. (p. 7-9 —7-10)	Up to 70 percent of the MSW waste stream is organic material. Yard trimmings alone constitute 20 percent of MSW. Composting organic materials can significantly reduce waste stream volume and offers economic advantages for communities when the costs of other options are high.
Developing and operating successful composting programs presents several challenges. (p. 7-10)	These challenges include the following: • developing markets and new end uses • inadequate or nonexisting standards for finished composts • inadequate design data for composting facilities • lack of experienced designers, vendors, and technical staff available to many municipalities • potential problems with odors • problems controlling contaminants • inadequate understanding of the biology and mathematics of composting.
The feedstock determines the chemical environment for composting. (p. 7-10 — 7-11)	Several factors determine the chemical environment for composting, especially: (a) the presence of an adequate carbon (food)/energy source, (b) a balanced amount of sufficient nutrients, (c) the correct amount of water, (d) adequate oxygen, (e) appropriate pH, and (f) the absence of toxic constituents that could inhibit microbial activity.
The ratio of carbon to nitrogen affects the rate of decomposition. (p. 7-12)	The ratio must be established on the basis of available carbon rather than total carbon. An initial ratio of 30:1 carbon:nitrogen is considered ideal. To lower the carbon:nitrogen ratios, nitrogen-rich materials (yard trimmings, animal manures, biosolids, etc.) are added.
Moisture content must be carefully monitored. (p. 7-12 — 7-13)	Because the water content of most feedstocks is not adequate, water is usually added to achieve the desired rate of composting. A moisture content of 50 to 60 percent of total weight is ideal. Excessive moisture can create anaerobic conditions, which may lead to rotting and obnoxious odors. Adding moisture may be necessary to keep the composting process performing at its peak. Evaporation from compost piles can also be minimized by controlling the size of piles.
Maintaining proper pH levels is important. (p. 7-13)	pH affects the amount of nutrients available to the microorganisms, the solubility of heavy metals, and the overall metabolic activity of the microorganisms. A pH between 6 and 8 is normal.

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Source reduction tops USEPA's composting methods hierarchy.

(p. 7-15)

Communities and individuals are encouraged to follow the hierarchy as listed below in order of preference: Grasscycling and home backyard composting completely divert materials from the MSW stream and should be adopted whenever possible.

Source-separated programs offer several advantages over mixed MSW programs, including: reduced handling time, less tipping space, and less pre-processing equipment. Mixed MSW composting offers fewer advantages over the long term.

1. Grasscycling (source reduction)
2. Backyard composting (source reduction)
3. Yard trimmings programs (recycling)
4. Source-separated organics composting (recycling)
5. MSW composting programs (recycling)

Planning a composting program involves these steps.

(p. 7-17 — 7-18)

1. Identify goals of the composting project.
2. Identify the scope of the project—backyard, yard trimmings, source-separated, mixed MSW, or a combination.
3. Get political support for changing the community's waste management approach.
4. Identify potential sites and environmental factors.
5. Identify potential compost uses and markets.
6. Initiate public information programs.
7. Inventory materials available for composting.
8. Visit successful compost programs.
9. Evaluate alternative composting and associated collection techniques.
10. Finalize arrangements for compost use.
11. Obtain necessary governmental approvals.
12. Prepare final budget and arrange financing.
13. Construct composting facilities and purchase collection equipment, if needed.
14. Initiate composting operation and monitor results.

Short- and long-term waste management needs determine composting program goals.

(p. 7-18)

Program goals may include one or more of the following:

- achieving mandated waste reduction goals through increased recycling.
- diverting specific materials, such as yard trimmings, biosolids, or any high-moisture organic waste, from landfills and incinerators.
- using compost as a replacement for daily cover (soil) in a landfill. In this case only a portion of the material may be composted to meet the daily cover needs, and the quality of compost generated is not critical.
- use for erosion control on highways, reservoirs, etc.

Political support for a composting project is critical.

(p. 7-19)

It is important to inform elected officials and government agencies of the project's goals and the developer's plans for implementing the project. Winning approval from an informed public can also be important for obtaining public funding. Without public approval, composting programs are difficult to successfully implement.

7 ❖ HIGHLIGHTS (continued)

Assess the amounts and quality of feedstock available. (p. 7-19 — 7-20)	Successful planning must be based on accurate data about quantities and sources of available feedstocks. This data helps determine the size and type of equipment needed and space requirements.
Two-way communication with the public is critical. (p. 7-20)	An effective education program is crucial to winning full public support. New waste management practices require substantial public education. Providing information about the nature of composting may help dispel any opposition to siting the composting facility. Potential problems such as odor should be openly and honestly discussed and strategies for addressing such problems developed.
The composting method chosen should be compatible with existing systems. (p. 7-21 — 7-22)	The composting option chosen must be compatible with existing processing systems. Communities should consider these factors: • preferences of the community • collection and processing costs • residual waste disposal costs • markets for the quality of compost produced • markets for recyclables • existing collection, processing and disposal systems.
There are four types of technologies for composting. (p. 7-22 — 7-26)	The four composting technologies are windrow, aerated static pile, in-vessel, and anaerobic composting. Supporting technologies include sorting, screening, and curing. The technologies vary in the method of air supply, temperature control, mixing/turning of the material, and the time required for composting. Their capital and operating costs also vary considerably.
Compost is screened to meet market specifications. (p. 7-26)	One or two screening steps and possibly additional grinding are used to prepare the compost for markets. For screening to successfully remove foreign matter and recover as much of the compost as possible, the compost's moisture content should be below 50 percent.
Final compost use and markets are crucial for program planning. (p. 7-27 — 7-28)	A well-planned marketing approach ensures that all compost will be distributed. Accomplishing this requires producing a consistently high-quality compost to satisfy market needs. The quality and composition required for a compost product to meet the needs of a specific market depend on a mix of factors, including intended use of the product, local climatic conditions, and even social and cultural factors.
Several states are considering regulating composts. (p. 7-27)	One approach for establishing regulations is to rely on the federal standards for land application of biosolids. Metals content of the applied material is an important concern. Table 7-2 shows the maximum metals content for land application of biosolids.

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Consider marketing to large-scale compost users.
(p. 7-28)

Large-scale users of composts include the following:

- farms
- landscape contractors
- highway departments
- sports facilities
- parks
- golf courses
- office parks
- home builders
- cemeteries
- nurseries
- growers of greenhouse crops
- manufacturers of topsoil.

Marketing success depends on a number of factors.
(p. 7-28 — 7-29)

Understanding the advantages and limitations of a given compost is important for marketing success. Marketers should focus on the qualities of the specific compost products, how they can meet customer needs, and what the compost can and cannot do. To target the right markets, you must know the potential uses of compost.

Major U.S. compost markets include those listed here.
(p. 7-28 — 7-30)

Major U.S. compost markets include the following (see Table 7-3):

- landscaping
- topsoil
- bagged for retail consumer use (residential)
- surface mine reclamation (active and abandoned mines)
- nurseries (both container and field)
- sod
- silviculture (Christmas trees, reforested areas, timber stand improvement)
- agriculture (harvested cropland, pasture/grazing land, cover crops).

The quality of a compost product directly impacts its marketability.
(p. 7-31 — 7-33)

Quality is judged primarily on particle size, pH, soluble salts, stability, and the presence of undesirable components such as weed seeds, heavy metals, phytotoxic compounds, and undesirable materials, such as plastic and glass. (Table 7-4 summarizes compost quality guidelines based on end use.) The marketability of a compost can be controlled by selectively accepting feedstock materials. Feedstock material should be carefully controlled to ensure consistent compost quality.

Backyard composting programs can significantly reduce the volume of MSW.
(p. 7-35 — 7-39)

In some communities, 30 or more percent of the MSW generated during the growing season is yard trimmings. Grasscycling and backyard composting programs reduce the need for collecting, processing, and disposing of the composted materials. Yard trimmings can be composted in piles or containers located in yards. Effective education and appropriate incentives are necessary to successfully implement community-wide backyard composting programs.

7 ❖ HIGHLIGHTS (continued)

Community-wide yard trimmings composting programs are another option.
(p. 7-39 — 7-42)

Community-wide yard trimmings composting programs divert significant quantities of materials from land disposal facilities. Grass and leaves make up the bulk of yard trimmings produced. Other materials include tree limbs, trunks and brush; garden materials such as weeds and pine needles; and Christmas trees. Both drop-off and curbside collection are possible.

Direct land-spreading of yard trimmings is an alternative.
(p. 7-45)

This approach bypasses the need to site and operate composting facilities. Direct land-spreading programs do have advantages, but they require careful management to avoid soil fertility problems if the carbon:nitrogen ratio is too high.

Source-separated organics composting programs are increasing.
(p. 7-45 — 7-46)

The definition of source-separated organics can include food scraps, yard trimmings, and sometimes paper. The advantage of source-separated organics composting is the ability to produce relatively contaminant-free compost. Accomplishing this depends on the conscientious efforts of generators and an effective collection program. A contaminant-free feedstock is important for producing a high-quality compost.

Mixed MSW composting also diverts materials from landfills.
(p. 7-47)

The source of feedstock for mixed MSW composting is usually residential and commercial solid waste. These programs do not require additional education and are more convenient for residents since special handling is not needed. The quality of the feedstock and consequently the compost product is enhanced when potential contaminants, such as household hazardous wastes, are segregated from the input stream through household hazardous waste programs (at the curb or facility).

Several technologies are available for composting mixed MSW.
(p. 7-47 — 7-51)

A two-stage process is often used: aerated static pile, in-vessel, or aerobic processes are usually the first stage and turned windrow or aerated static pile is the second-stage curing technology. The combination of technologies depends on the process selected, space and odor considerations, economics, and operating preferences.

Concerns about mixed MSW compost must be addressed.
(p. 7-51)

One of the primary concerns is the presence of heavy metal compounds (particularly lead) and toxic organic compounds in the MSW compost product. Measures, including source separation, can be taken to prevent problems and produce a high quality compost. Testing for chemical constituents must be carefully planned and executed to ensure production of a consistently high-quality product.

Leachate at composting facilities must be contained and treated.
(p. 7-52)

Even well-managed facilities generate small quantities of leachate. The facility's design should include a paved floor and outdoor paved area equipped with drains leading to a leachate collection tank or collection pond. For outdoor compost piles, attempts must be made to minimize leachate production by diverting any surface-water runoff from the up-slope side of the piles.

❖❖❖

Odor and dust control are crucial when operating a compost facility.

(p. 7-52 — 7-53)

The source and type of odor should be identified. The degree of odor control needed depends in part on the facility's proximity to residences, businesses, schools, etc. Siting a facility at a remote location provides a large buffer zone between the facility and any residents and helps to alleviate odor-related complaints.

Operators should be aware of *Aspergillus fumigatus*, a fungus naturally present in decaying organic matter. Workers susceptible to respiratory problems or with impaired immune systems are not good candidates for working in composting facilities.

Routine testing and monitoring is an essential part of any composting operation.

(p. 7-53)

At a minimum the following should be monitored:

- compost mass temperatures
- oxygen concentrations in the compost mass
- moisture content
- particle size
- maturity of the compost
- pH
- soluble salts
- ammonia
- organic and volatile materials content.

Keeping records is essential.

(p. 7-54)

Periodically evaluating records helps identify where improvements are needed and provides information necessary for making the operation more efficient. All employees should understand the importance of keeping good records. Records should be kept on employee safety training, facility and employee safety procedures, and health monitoring at the facility.

Communication with community leaders and facility neighbors should be ongoing.

(p. 7-54 — 7-55)

To ensure good relations, the public should be informed of the types of materials accepted and prohibited and the collection schedules. Periodically remind residents that composting is an effective management tool. A complaint response procedure is also important. Document and respond to complaints promptly.

Composting facilities may require approvals or permits.

(p. 7-56)

The requirements for permitting composting facilities may vary among states. In addition to state-level permits, local permits may be required, such as building permits, zoning variances, or special land use permits.

Financing is an integral part of planning a composting project.

(p. 7-56)

The most common methods of financing a large-scale composting project (e.g., to service a municipality) are through bond sales or bank loans. A financing professional should be consulted.

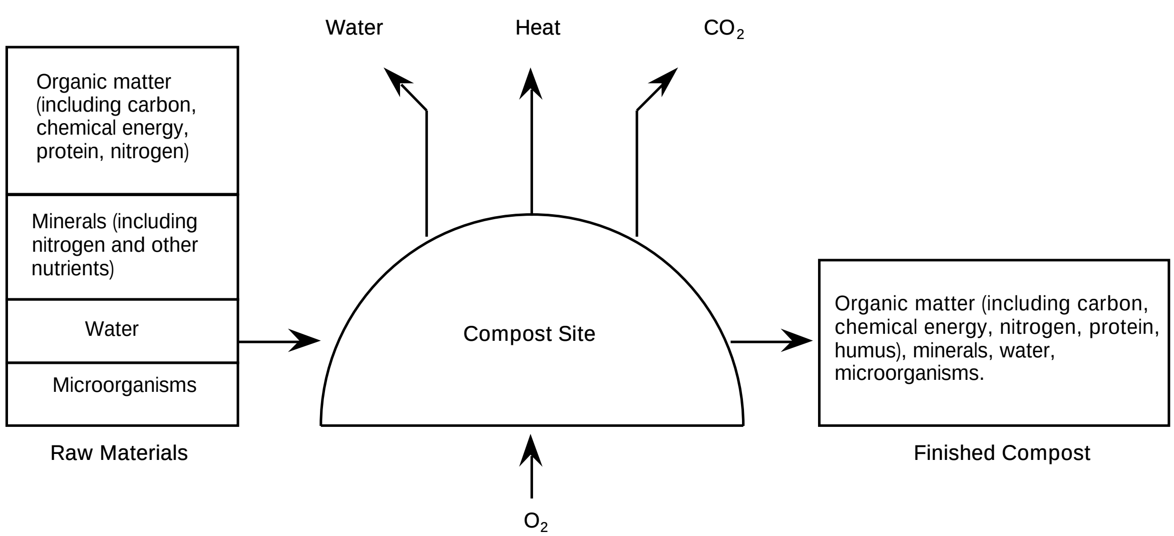
7 COMPOSTING

WHAT IS COMPOSTING?

Composting as a Biological Process

Composting involves the aerobic biological decomposition of organic materials to produce a stable humus-like product (see Figure 7-1). Biodegradation is a natural, ongoing biological process that is a common occurrence in both human-made and natural environments. Grass clippings left on the lawn to decompose or food scraps rotting in a trash can are two examples of uncontrolled decomposition. To derive the most benefit from this natural, but typically slow, decomposition process, it is necessary to control the environmental conditions during the composting process. Doing so plays a significant role in increasing and controlling the rate of decomposition and determining the quality of the resulting compost.

Figure 7-1
The Composting Process



The carbon, chemical energy, protein, and water in the finished compost is less than that in the raw materials. The finished compost has more humus. The volume of the finished compost is 50% or less of the volume of raw material.

Source: Reprinted with permission from Rynk, et al., *On Farm Composting Handbook, 1992 (NRAES-54)*

Good-quality compost is devoid of weed seeds and pathogenic organisms, relatively stable and resistant to further rapid decomposition by microorganisms.

Compost is the end product of the composting process, which also produces carbon dioxide and water as by-products. Composts are humus, which is dark in color, peat-like, has a crumbly texture and an earthy odor, and resembles rich topsoil. The final product has no resemblance in physical form to the original waste from which the compost was made. Good-quality compost is devoid of weed seeds and organisms that may be pathogenic to humans, animals, or plants. Cured compost is also relatively stable and resistant to further rapid decomposition by microorganisms.

Composting and co-composting are two commonly used terms. Composting is a broader term that includes co-composting. While composting refers to the decomposition of any organic materials (also referred to as "feedstocks"), co-composting is the composting of two or more feedstocks with different characteristics—for example, the co-composting of biosolids in liquid / dewatered form with yard trimmings and leaves.

It is important to view compostable materials as usable, *not* as waste requiring disposal. When developing and promoting a composting program and when marketing the resulting compost, program planners and managers should stress that the composting process is an environmentally sound and beneficial means of recycling organic materials, *not* a means of waste disposal.

In the broadest sense, any organic material that can be biologically decomposed is "compostable." In fact, humans have used this naturally occurring process for centuries to stabilize and recycle agricultural and human wastes. Today, composting is a diverse practice that includes a variety of approaches, depending on the types of organic materials being composted and the desired properties of the final product.

Composting as a Component of Integrated Solid Waste Management

Composting is one component in USEPA's integrated solid waste management hierarchy.

Composting is one component in USEPA's hierarchy of integrated solid waste management, which is discussed in the introduction to this guidebook (see Figure I-1 in the introduction). Source reduction tops the hierarchy of management options, with recycling as the next preferred option. Grasscycling and backyard composting are forms of source reduction or waste prevention because the materials are completely diverted from the disposal facilities and require no management or transportation. Community yard trimmings composting programs, source-separated organics composting, and mixed MSW composting are considered forms of recycling. Each of these approaches to composting is discussed in the section later in this chapter titled "Composting Approaches in Detail."

This chapter provides information about methods and programs for composting yard trimmings (leaves, grass clippings, brush, and tree prunings) or the compostable portion of mixed solid waste (MSW), including yard trimmings, food scraps, scrap paper products, and other decomposable organics.

The Benefits of Composting

Composting organic materials can significantly reduce waste stream volume.

Municipal solid wastes contain up to 70 percent by weight of organic materials. Yard trimmings, which constitute 20 percent of the MSW stream, may contain even larger proportions of organic materials. In addition, certain industrial by-products—those from the food processing, agricultural, and paper industries—are mostly composed of organic materials. Composting organic materials, therefore, can significantly reduce waste stream volume. Diverting such materials from the waste stream frees up landfill space needed for materials that cannot be composted or otherwise diverted from the waste stream.

Composting owes its current popularity to several factors, including increased landfill tipping fees, shortage of landfill capacity, and increasingly restrictive measures imposed by regulatory agencies. In addition, composting is indirectly encouraged by states with recycling mandates that include composting as an acceptable strategy for achieving mandated goals, some of which reach 50-60 percent (Apotheker, 1993). Consequently, the number of existing or planned composting programs and facilities has increased significantly in recent years.

The benefits of reducing disposal needs through composting may be adequate to justify choosing this option even if the compost is used for landfill cover.

Composting may also offer an attractive economic advantage for communities in which the costs of using other options are high. Composting is frequently considered a viable option only when the compost can be marketed—that is, either sold or given away. In some cases, however, the benefits of reducing disposal needs through composting may be adequate to justify choosing this option even if the compost is used for landfill cover.

Composts, because of their high organic matter content, make a valuable soil amendment and are used to provide nutrients for plants. When mixed into the soil, compost promotes proper balance between air and water in the resulting mixture, helps reduce soil erosion, and serves as a slow-release fertilizer.

Composting Challenges

Despite the growing popularity of composting, communities face several significant challenges in developing and operating successful composting programs. These include the following:

- developing markets and new end uses
- inadequate or nonexisting standards for finished composts
- inadequate design data for composting facilities
- lack of experienced designers, vendors, and technical staff available to many municipalities
- potential problems with odors
- problems controlling contaminants
- inadequate understanding of the biology and mathematics of composting
- inadequate financial planning.

The failure to control the quality of the compost directly impacts its marketability.

Many existing mixed MSW composting facilities have an over-simplified design that focuses primarily on the production aspects of composting and inadequately addresses factors crucial to producing a high-quality, marketable product. For example, many facilities have limited capabilities to separate compostable materials from the non-compostable fraction before the composting process is begun. Because the quality of the end product is determined by the type of materials that are being composted, inadequate separation of materials can adversely affect compost quality. Similarly, processing to remove physical contaminants is sometimes ignored or done inadequately. The failure to control the quality of the compost directly impacts its marketability. As a result, market development has not kept pace with compost production, which in turn has led to under-capitalized projects.

Inadequate storage space for curing compost to maturity has also been a problem at some facilities. Designing adequate storage space should be an important part of planning and developing facilities. Odors associated with storing organics before composting and odors produced during composting pose a significant challenge for many facilities. The inability to adequately deal with potential or existing odor problems can and has contributed to the closure of some facilities.

THE BIOLOGICAL, CHEMICAL, AND PHYSICAL COMPOSTING PROCESSES

Many factors contribute to the success of the composting process. This section provides a technical discussion of these factors and gives readers who lack a technical background a more in-depth understanding of the basic composting processes. Understanding these processes is necessary for making informed decisions when developing and operating a composting program.

Biological Processes

Peak performance by microorganisms requires that their biological, chemical, and physical needs be maintained at ideal levels throughout all stages of composting.

Peak performance by microorganisms requires that their biological, chemical, and physical needs be maintained at ideal levels throughout all stages of composting. Microorganisms such as bacteria, fungi, and actinomycetes play an active role in decomposing the organic materials. Larger organisms such as insects and earthworms are also involved in the composting process, but they play a less significant role compared to the microorganisms.

As microorganisms begin to decompose the organic material, the carbon in it is converted to by-products like carbon dioxide and water, and a humic end product—compost. Some of the carbon is consumed by the microorganisms to form new microbial cells as they increase their population. Heat is released during the decomposition process.

Microorganisms have preferences for the type of organic material they consume. When the organic molecules they require are not available, they may become dormant or die. In this process, the humic end products resulting from the metabolic activity of one generation or type of microorganism may be used as a food or energy source by another generation or type of microorganism. This chain of succession of different types of microbes continues until there is little decomposable organic material remaining. At this point, the organic material remaining is termed compost. It is made up largely of microbial cells, microbial skeletons and by-products of microbial decomposition and undecomposed particles of organic and inorganic origin. Decomposition may proceed slowly at first because of smaller microbial populations, but as populations grow in the first few hours or days, they rapidly consume the organic materials present in the feedstock.

The number and kind of microorganisms are generally not a limiting environmental factor in composting nontoxic agricultural materials, yard trimmings, or municipal solid wastes, all of which usually contain an adequate diversity of microorganisms. However, a lack of microbial populations could be a limiting factor if the feedstock is generated in a sterile environment or is unique in chemical composition and lacks a diversity of microorganisms. In such situations it may be necessary to add an inoculum of specially selected microbes. While inocula speed the composting process by bringing in a large population of active microbes, adding inocula is generally not needed for composting yard trimmings or municipal solid wastes. Sometimes, partially or totally composted materials (composts) may be added as an inoculum to get the process off to a good start. It is not necessary to buy "inoculum" from outside sources. A more important consideration is the carbon:nitrogen ratio, which is described in a later section.

The composting process should cater to the needs of the microorganisms and promote conditions that will lead to rapid stabilization of the organic materials.

Microorganisms are the key in the composting process. If all conditions are ideal for a given microbial population to perform at its maximum potential, composting will occur rapidly. The composting process, therefore, should cater to the needs of the microorganisms and promote conditions that will lead to rapid stabilization of the organic materials.

While several of the microorganisms are beneficial to the composting process and may be present in the final product, there are some microbes that are potential pathogens to animals, plants, or humans. These pathogenic organisms must be destroyed in the composting process and before the compost is distributed in the market place. Most of this destruction takes place by controlling the composting operation's temperature, a physical process that is described below.

Chemical Processes

The chemical environment is largely determined by the composition of material to be composted. In addition, several modifications can be made during the composting process to create an ideal chemical environment for rapid decomposition of organic materials. Several factors determine the chemical environment for composting, especially: (a) the presence of an adequate carbon (food)/energy source, (b) a balanced amount of nutrients, (c) the correct amount of water, (d) adequate oxygen, (e) appropriate pH, and (f) the absence of toxic constituents that could inhibit microbial activity.

Carbon/Energy Source

Microorganisms in the compost process are like microscopic plants: they have more or less the same nutritional needs (nitrogen, phosphorus, potassium, and other trace elements) as the larger plants. There is one important exception, however: compost microorganisms rely on the carbon in organic material as their carbon/energy source instead of carbon dioxide and sunlight, which is used by higher plants.

How easily biodegradable a material is depends on the genetic makeup of the microorganism present and the makeup of the organic molecules that the organism decomposes.

The carbon contained in natural or human-made organic materials may or may not be biodegradable. The relative ease with which a material is biodegraded depends on the genetic makeup of the microorganism present and the makeup of the organic molecules that the organism decomposes. For example, many types of microorganisms can decompose the carbon in sugars, but far fewer types can decompose the carbon in lignins (present wood fibers), and the carbon in plastics may not be biodegradable by any microorganisms. Because most municipal and agricultural organics and yard trimmings contain adequate amounts of biodegradable forms of carbon, carbon is typically not a limiting factor in the composting process.

As the more easily degradable forms of carbon are decomposed, a small portion of the carbon is converted to microbial cells, and a significant portion of this carbon is converted to carbon dioxide and lost to the atmosphere. As the composting process progresses, the loss of carbon results in a decrease in weight and volume of the feedstock. The less-easily decomposed forms of carbon will form the matrix for the physical structure of the final product—compost.

Nutrients

Among the plant nutrients (nitrogen, phosphorus, and potassium), nitrogen is of greatest concern because it is lacking in some materials. The other nutrients are usually not a limiting factor in municipal solid waste or yard trimmings feedstocks. The ratio of carbon to nitrogen is considered critical in determining the rate of decomposition. Carbon to nitrogen ratios, however, can often be misleading. The ratio must be established on the basis of *available* carbon rather than *total* carbon. In general, an initial ratio of 30:1 carbon:nitrogen is considered ideal. Higher ratios tend to retard the process of decomposition, while ratios below 25:1 may result in odor problems. Typically, carbon to nitrogen ratios for yard trimmings range from 20 to 80:1, wood chips 400 to 700:1, manure 15 to 20:1, and municipal solid wastes 40 to 100:1. As the composting process proceeds and carbon is lost to the atmosphere, this ratio narrows. Finished compost should have ratios of 15 to 20:1.

An initial ratio of 30:1 carbon:nitrogen is considered ideal.

To lower the carbon:nitrogen ratios, nitrogen-rich materials such as yard trimmings, animal manures, or biosolids are often added. Adding partially decomposed or composted materials (with a lower carbon:nitrogen ratio) as inoculum may also lower the ratio. Attempts to supplement the nitrogen by using commercial fertilizers often create additional problems by modifying salt concentrations in the compost pile, which in turn impedes microbial activity. As temperatures in the compost pile rise and the carbon:nitrogen ratio falls below 25:1, the nitrogen in the fertilizer is lost in a gas form (ammonia) to the atmosphere. This ammonia is also a source of odors.

Moisture

Water is an essential part of all forms of life and the microorganisms living in a compost pile are no exception. Because most compostable materials have a

A moisture content of 50 to 60 percent of total weight is considered ideal.

lower-than-ideal water content, the composting process may be slower than desired if water is not added. However, moisture-rich solids have also been used. A moisture content of 50 to 60 percent of total weight is considered ideal. The moisture content should not be great enough, however, to create excessive free flow of water and movement caused by gravity. Excessive moisture and flowing water form leachate, which creates a potential liquid management problem and potential water pollution and odor problems. Excess moisture also impedes oxygen transfer to the microbial cells. Excessive moisture can increase the possibility of anaerobic conditions developing and may lead to rotting and obnoxious odors.

Microbial processes contribute moisture to the compost pile during decomposition. While moisture is being added, however, it is also being lost through evaporation. Since the amount of water evaporated usually exceeds the input of moisture from the decomposition processes, there is generally a net loss of moisture from the compost pile. In such cases, adding moisture may be necessary to keep the composting process performing at its peak. Evaporation from compost piles can be minimized by controlling the size of piles. Piles with larger volumes have less evaporating surface / unit volume than smaller piles. The water added must be thoroughly mixed so all portions of the organic fraction in the bulk of the material are uniformly wetted and composted under ideal conditions. A properly wetted compost has the consistency of a wet sponge. Systems that facilitate the uniform addition of water at any point in the composting process are preferable.

Oxygen

The compost pile should have enough void space to allow free air movement so that oxygen from the atmosphere can enter the pile.

Composting is considered an *aerobic* process, that is, one requiring oxygen. *Anaerobic* conditions, those lacking oxygen, can produce offensive odors. While decomposition will occur under both aerobic and anaerobic conditions, aerobic decomposition occurs at a much faster rate. The compost pile should have enough void space to allow free air movement so that oxygen from the atmosphere can enter the pile and the carbon dioxide and other gases emitted can be exhausted to the atmosphere. In some composting operations, air may be mechanically forced into or pulled from the piles to maintain adequate oxygen levels. In other situations, the pile is turned frequently to expose the microbes to the atmosphere and also to create more air spaces by fluffing up the pile.

A 10 to 15 percent oxygen concentration is considered adequate, although a concentration as low as 5 percent may be sufficient for leaves. While higher concentrations of oxygen will not negatively affect the composting process, they may indicate that an excessive amount of air is circulating, which can cause problems. For example, excess air removes heat, which cools the pile. Too much air can also promote excess evaporation, which slows the rate of composting. Excess aeration is also an added expense that increases production costs.

pH

A pH between 6 and 8 is considered optimum. pH affects the amount of nutrients available to the microorganisms, the solubility of heavy metals, and the overall metabolic activity of the microorganisms. While the pH can be adjusted upward by addition of lime or downward with sulfur, such additions are normally not necessary. The composting process itself produces carbon dioxide, which, when combined with water, produces carbonic acid. The carbonic acid could lower the pH of the compost. As the composting process progresses, the final pH varies depending on the specific type of feedstocks used and operating conditions. Wide swings in pH are unusual. Because organic materials are naturally well-buffered with respect to pH changes, down swings in pH during composting usually do not occur.

Physical Processes

The physical environment in the compost process includes such factors as temperature, particle size, mixing, and pile size. Each of these is essential for the composting process to proceed in an efficient manner.

Particle Size

The optimum particle size has enough surface area for rapid microbial activity, but also enough void space to allow air to circulate for microbial respiration.

The particle size of the material being composted is critical. As composting progresses, there is a natural process of size reduction. Because smaller particles usually have more surface per unit of weight, they facilitate more microbial activity on their surfaces, which leads to rapid decomposition. However, if all of the particles are ground up, they pack closely together and allow few open spaces for air to circulate. This is especially important when the material being composted has a high moisture content. The optimum particle size has enough surface area for rapid microbial activity, but also enough void space to allow air to circulate for microbial respiration. The feedstock composition can be manipulated to create the desired mix of particle size and void space. For yard trimmings or municipal solid wastes, the desired combination of void space and surface area can be achieved by particle size reduction. Particle size reduction is sometimes done after the composting process is completed to improve the aesthetic appeal of finished composts destined for specific markets.

Temperature

The optimum temperature range is 32°-60°C.

All microorganisms have an optimum temperature range. For composting this range is between 32° and 60° C. For each group of organisms, as the temperature increases above the ideal maximum, thermal destruction of cell proteins kills the organisms. Likewise, temperatures below the minimum required for a group of organisms affects the metabolic regulatory machinery of the cells. Although composting can occur at a range of temperatures, the optimum temperature range for thermophilic microorganisms is preferred, for two reasons: to promote rapid composting and to destroy pathogens and weed seeds. Larger piles build up and conserve heat better than smaller piles. Temperatures above 65° C are not ideal for composting. Temperatures can be lowered if needed by increasing the frequency of mechanical agitation, or using blowers controlled with timers, temperature feedback control, or air flow throttling. Mixing or mechanical aeration also provides air for the microbes.

Ambient air temperatures have little effect on the composting process, provided the mass of the material being composted can retain the heat generated by the microorganisms. Adding feedstock in cold weather can be a problem especially if the feedstock is allowed to freeze. If the feedstock is less than 5° C, and the temperature is below freezing, it may be very difficult to start a new pile. A better approach is to mix cold feedstock into warm piles. Once adequate heat has built up, which may be delayed until warmer weather, the processes should proceed at a normal rate.

Pathogen destruction is achieved when compost is at a temperature of greater than 55° C for at least three days. It is important that all portions of the compost material be exposed to such temperatures to ensure pathogen destruction throughout the compost. At these temperatures, weed seeds are also destroyed. After the pathogen destruction is complete, temperatures may be lowered and maintained at slightly lower levels (51° to 55° C).

Attaining and maintaining 55° C temperatures for three days is not difficult for in-vessel composting systems. However, to achieve pathogen destruction with windrow composting systems, the 55° C temperature must be maintained for a minimum of 15 days, during which time the windrows must be turned at least five times. The longer duration and increased turning are necessary to achieve uniform pathogen destruction throughout the entire pile.

Care should be taken to avoid contact between materials that have achieved these minimum temperatures and materials that have not. Such contact could recontaminate the compost.

Compost containing municipal wastewater treatment plant biosolids must meet USEPA standards applicable to biosolids pathogen destruction. This process of pathogen destruction is termed "process to further reduce pathogens" (PFRP). States may have their own minimum criteria regulated through permits issued to composting facilities. A state's pathogen destruction requirement may be limited to compost containing biosolids or it may apply to all MSW compost.

Mixing and agitation distribute moisture and air evenly.

Mixing

Mixing feedstocks, water, and inoculants (if used) is important. Piles can be turned or mixed after composting has begun. Mixing and agitation distribute moisture and air evenly and promote the breakdown of compost clumps. Excessive agitation of open vessels or piles, however, can cool the piles and retard microbial activity.

AN OVERVIEW OF COMPOSTING APPROACHES

USEPA emphasizes the following hierarchy of composting methods in order of preference. A detailed discussion of each approach can be found in the "Composting Approaches in Detail" section later in this chapter.

1. Grasscycling (source reduction)
2. Backyard Composting (source reduction)
3. Yard Trimmings Programs (recycling)
4. Source-Separated Organics Composting (recycling)
5. MSW Composting Programs (recycling)

Grasscycling and Backyard Composting

In 1990, yard trimmings constituted nearly 18 percent of the total MSW waste stream in the United States (USEPA, 1992). Because grasscycling and home backyard composting programs are source reduction methods, that is they completely divert the materials from entering the municipal solid waste stream, USEPA encourages communities to promote these composting approaches whenever possible.

Grasscycling

Grasscycling is a form of source reduction that involves the natural recycling of grass clippings by leaving the clippings on the lawn after mowing. In one study, researchers found that grasscycling reduced lawn maintenance time by 38 percent. In addition, leaving grass clippings on the lawn reduces the need to fertilize by 25 to 33 percent, because nutrients in the grass clippings are simply being recycled. A 25 to 33 percent fertilizer savings can normally be achieved. Grasscycling also reduces or eliminates the need for disposal bags and for pick-up service charges, as well.

Labor and the amount of fertilizer required decrease with grasscycling.

Backyard Composting

Many communities have established programs to encourage residents to compost yard trimmings and possibly other organic materials in compost piles or containers located on their property. Because the materials are used by resi-

Backyard recycling is increasing in popularity.

dents and never enter the waste stream, this method is also considered source reduction. Backyard composting is increasing as more communities recognize its potential for reducing waste volumes which may be as much as 850 pounds of organic materials per household per year, according to one estimate (Roulac, J. and M. Pedersen, 1993).

Source-Separated Organics Composting Programs

Source separation minimizes the amount of handling time, tipping space and pre-processing equipment required in mixed MSW composting.

Source-separated composting programs rely on residents, businesses, and public and private institutions to separate one or more types of organic materials and set them out separately from other recyclables and trash for collection. Source separation of organics can offer several advantages over mixed MSW composting. For example, source separation minimizes the amount of handling time, tipping space and pre-processing equipment that is usually required in mixed MSW composting. In addition, source-separated composting produces a consistently higher-quality compost because the feedstock is relatively free of noncompostable materials and potential chemical and heavy metal contaminants (Gould, et al., 1992). Table 7-1 shows the comparative benefits and disadvantages of source-separated organics composting programs and mixed MSW composting.

Several approaches to source-separated composting exist. In general, some mix of the following materials are included, depending on the design of the specific program (Gould, et al., 1992):

- yard trimmings (which can include grass, leaves, and brush)
- food scraps (from residential, industrial or institutional sources)
- mixed paper (which may or may not be included because it requires shredding and must be mixed with other materials)
- disposable diapers (like paper, require special treatment, and may or may not be included)
- wood scraps

The number of source-separated composting programs and facilities in the United States is steadily increasing. For example, in early 1994, New York state alone had more than 20 institutional food and yard trimmings facilities located at prisons, colleges, campuses and resorts; two pilot residential source-separated facilities; and one full-scale facility.

Table 7-1

Advantages and Disadvantages of Source Separation versus Commingling MSW

Source-Separated Materials	Commingled Materials
Advantages: • Less chance of contamination. This can result in a higher-quality compost product. • Less money and time spent on handling and separating materials at the composting facility. • Provides an educational benefit to residents and might encourage waste reduction.	*Advantages* • Usually collected with existing equipment and labor resources. • Convenient for residents because no separation is required.
Disadvantages: • Can be less convenient to residents. • Might require the purchase of new equipment and/or containers. • Might require additional labor for collection.	*Disadvantages:* • Higher potential for contamination, which can result in a lower-quality compost product. • Higher processing and facility costs.

Source: USEPA, 1994

Nationwide, in 1994 there were approximately 3,000 yard trimmings composting programs in the United States. State and local bans on landfilling and combusting yard trimmings have contributed to the growing number of such programs. In 1994, 27 states and Washington DC banned all or some components of yard trimmings from land disposal.

Mixed Municipal Solid Waste Composting

USEPA places mixed MSW composting at the bottom of the composting hierarchy.

Some MSW composting programs in the U.S. use a commingled stream of organic materials. In such programs, mixed MSW is first sorted to remove recyclable, hazardous, and noncompostable materials, and the remaining organic materials are then composted. As mentioned above, USEPA places mixed MSW composting at the bottom of its hierarchy of composting approaches. Although mixed MSW composting programs may offer some advantages (see Table 7-1)—for example, materials can usually be collected with existing equipment, residents do not have to separate materials themselves and only need one container—home recycling, yard trimmings, and source-separated composting are increasingly being seen as offering more advantages, especially over the long-term.

DEVELOPING A COMPOSTING PROGRAM

Evaluating Waste Management Alternatives

Communities faced with the task of selecting any solid waste management alternative should consider both monetary and intangible environmental factors in evaluating the various solid waste management alternatives available to them.

No single solid waste management option can solve all of a community's waste problems.

Often there is disagreement among citizens, planners, and decision makers about the best alternative for the community. According to the principles of integrated waste management, no single solid waste management option can solve all of a community's waste problems. To achieve their specific solid waste management goals, communities often combine approaches and alternatives. The options a community selects should complement each other, and the justifications used to select alternatives should be defensible not only during planning, but also during the implementation and operational periods for each alternative chosen.

Selecting the best solid waste management option must be based on goals and evaluation criteria that the community adopts early in the planning process. Any and all options should be given equal consideration initially. Frequently, when communities choose alternatives without considering all of the available options, extensive modifications to the hastily chosen alternative are eventually needed. The result is soaring costs and sometimes total abandonment of the facility and the equipment acquired for the failed project.

Planning the Program

If a community decides that composting is a viable and desirable alternative, there are several steps involved in planning a composting program. A well-planned program and facility will pose few operational difficulties, keep costs within projected budgets, consistently produce a good-quality compost, identify and keep adequate markets for the amount of compost produced, and have continuing support from the community. Below is an outline presenting 14 steps for developing and implementing a successful composting program.

Well-planned programs pose few operational difficulties, follow budgets, produce a good-quality compost and market all of it, and maintain community support.

1. Identify goals of the composting project.
2. Identify the scope of the project (backyard, yard trimmings, source-separated, mixed MSW, or a combination).
3. Gather political support for changing the community's waste management approach.
4. Identify potential sites and environmental factors.
5. Identify potential compost uses and markets.
6. Initiate public information programs.
7. Inventory materials available for composting.
8. Visit successful compost programs.
9. Evaluate alternative composting and associated collection techniques.
10. Finalize arrangements for compost use.
11. Obtain necessary governmental approvals.
12. Prepare final budget and arrange financing, including a contingency fund.
13. Construct composting facilities and purchase collection equipment, if needed.
14. Initiate composting operation and monitor results.

Identifying Composting Project Goals

The goals of any composting project must be clearly identified during the earliest planning stages of the project. Some goals may be further evaluated and redefined during the course of the project, but the project's core goals (for example, reducing the volume of material landfilled, reducing collection costs, or augmenting other reduction efforts) should remain intact because such goals determine how subsequent decisions are made throughout much of the program's development and implementation.

Base goals on the community's short- and long-term solid waste management needs.

Goals must be determined based on the community's short- and long-term solid waste management needs. The project may have multiple goals:

- achieving mandated waste reduction goals by increasing the amount of material recycled.
- diverting specific materials, such as yard trimmings, biosolids, or any high-moisture organic waste, from landfills and incinerators.
- using compost as a replacement for daily cover (soil) in a landfill. In this case only a portion of the material may be composted to meet the daily cover needs, and the quality of compost generated is not critical.
- using compost for erosion control on highways, reservoirs and other applications. (U.S. Department of Transportation regulations provide for use of compost under certain conditions.)

Producing a marketable product (compost) and recovering revenues by selling the compost is another possible goal. In this case, the composting project should be viewed as a commercial production process. Selling compost on the open market requires that the compost meet high standards and be of a consistent quality. A detailed market evaluation should be made when considering this goal (see the "Marketing" section below). No matter what the program's goals are, they should be clearly defined to garner political support for the project. Such goals should be compatible with the community's overall solid waste management plan, including collection and landfilling.

Goals should be clearly defined.

Finally, clearly defining the project's goals saves time during the planning and implementation process. Clearly defined goals help focus activities and resources and prevent wasting efforts on activities that do not contribute to reaching those goals.

Obtaining Political Support for a New Waste Management Approach

Most composting projects, whether municipally or privately operated, will require some governmental support or approval. This may be as simple as local government financing of advertising and education materials. Larger government expenditures may be needed, depending on the composting technique selected. Private programs require siting and perhaps other permits.

Political consensus and support is critical.

To gain political support, it is crucial to inform elected officials and government agencies of the project's goals and the developer's plans for implementing the project. It is also important to solicit input during the early stages of project development from government officials and agencies, especially those responsible for solid waste management.

To elicit support, it may be helpful to arrange for decision makers to visit successful composting facilities. Seeing a successful project in operation provides decision makers with first-hand information that may be useful in evaluating and planning a similar program in their own community.

Engage the officials and concerned members of the public in an open dialogue and do not be surprised if objections are raised. Such objections should be answered without deviating from the project's goals.

Positive media coverage of such projects helps put them on the public agenda, which is usually required to gain widespread community support. Winning approval from an informed public can also be important for obtaining public funding.

If political support is not forthcoming, get a clear picture of the concerns that decision makers have about the proposed project and work to address those concerns. Visits to well-managed facilities in the region may help to assure decision makers that some of their concerns can be successfully addressed. It may also be helpful to consider modifying the project's goals to address some concerns. If support is still lacking or if there is strong opposition to the project, planners should consider abandoning the project.

Identifying Potential Compost Uses and Markets

A useful purpose must be found for the materials recovered from the composting process. In general, the uses for compost include agricultural applications, nurseries and greenhouses, surface mine reclamation, forestry applications, as a topsoil, landscaping, soil remediation, roadside landscaping management, and as final cover in landfill operations. Marketing compost products is crucial to the success of any program and is discussed in detail in the "Marketing" section of this chapter.

Inventorying Potential Sources of Compostable Materials

The planning process should include an accurate assessment of the quantities of materials available for processing and their composition and sources. Chapter 3 provides a detailed discussion of methods for estimating feedstock quantities and composition. Such data can help determine the size and type of equipment the planned facility will need and also the facility's space requirements. The quantity of feedstock processed and the equipment selected will in turn help determine the program's labor needs and the economics of operation.

Conduct a waste quantity characterization study to get an accurate assessment.

Although quantity and composition data may be available from waste haulers, landfills, or other sources, data from such sources may not be reliable for several reasons. The sources from which such data were compiled may not be known or may be incomplete; furthermore, recent increases in recycling and changes in technology make anything but the most recent information irrelevant. Published data should, therefore, be used cautiously. It is far better to obtain as much original data as possible (see Chapter 3 for a discussion of data collection methods).

Composition data should be obtained for each source separately. Data should be collected for at least one year, so as to represent seasonal fluctuations in composition. Although projecting waste stream composition for future years is especially difficult, it is essential to know the compostable proportion of the current waste stream and how much of this material can be realistically separated from the non-compostable fraction before composting. This will help identify the need for any modifications of the collection system.

Program developers must also decide whether to include industrial or commercial materials in the composting program. If such materials are included, they must be carefully evaluated for their compostable fraction, and methods for segregating and collecting them should be developed.

If the community does not already have a household hazardous waste collection program, then planners should consider whether to institute one. In addition to diverting hazardous materials from landfills and combustion facilities, household hazardous waste programs help eliminate contaminants from composting feedstock, which in turn can contribute to producing a consistently higher quality compost product.

Consider the major long-term trends and changes in management strategies already underway.

When planning a program or facility, it is also crucial to consider the major long-term trends and changes in management strategies already underway. For example, the USEPA and many state governments have made source reduction their highest priority waste management strategy. As mentioned earlier in this chapter, source reduction programs and strategies aim at reducing the volume of discarded materials generated by sources (including residents, industries, and institutions) and changing production and consumption patterns, all of which may have long-term impacts on waste volumes and composition. It is essential that such measures be considered when determining long-term estimates of a community's waste stream volume and composition. It is also crucial to consider the community's own long-term waste management plans, given current, and possibly future, local, state, and federal regulations and programs.

Initiating Education and Information Programs

Establishing an effective two-way communication process between project developers and the public is crucial, and public involvement in the project must begin during the planning stages. Concerns voiced by public representatives should be addressed as early in the project's development as possible.

Any new approach to waste management will be questioned by some sectors of the community before it is fully embraced, and an effective education program is crucial to winning full public support. In addition, new waste management practices require substantial public education efforts because they usually require some changes in the public's waste management behavior. For example, new source-separated programs require residents to change the way they sort discarded materials. In some composting programs, residents are also required to separate out household hazardous wastes. As requirements for input from generators increase, so does the importance of public education for ensuring a high rate of compliance.

Education programs should provide factual information about the composting process and potential problems.

The education program should provide objective, factual information about the composting process and potential problems that may be associated with composting facilities. Often, residents equate a composting facility with a waste disposal facility and oppose siting such a facility in their area for that reason. Similarly, some residents may view drop-off sites (for yard trimmings) as disposal sites and oppose them. Providing information about the nature of composting may help dispel such opposition. At the same time, potential problems such as odor should be openly and honestly discussed and strategies for addressing such problems developed. Public education programs and the importance of public involvement in any waste management, recycling, or composting program are discussed in Chapter 1.

Choosing a Composting Approach

Compatibility with Existing Programs

Whichever approach is chosen, it should be compatible with existing collection, processing, and disposal systems. All composting facilities require some degree of material separation, which can take place at the source (as with source-separated programs) or at the processing facility (as with mixed MSW composting programs). Some communities already require generators to separate recyclable from nonrecyclable materials (two-stream collection programs). Others require a three-stream separation into a compostable fraction, a recyclable but noncompostable fraction, and nonrecyclable fraction. Yet other communities choose to collect mixed waste and attempt to separate compostable, recyclable and nonrecyclable materials at the composting facility.

Examine the costs of various options and the level of generator involvement required for each.

The costs of the various collection options should be carefully examined, as should the level of generator involvement required for each. For example, mixed MSW composting may have economic advantages during collection compared to source-separated programs, which may require more intensive education (because of higher generator involvement) and, possibly, separate collection. Mixed MSW composting has increased capital and labor costs, however, which may offset the savings in collection costs. In addition, source-separated programs may offer other benefits, such as a consistently higher-quality compost product and lower daily operating expenses because less complicated machinery is required (Hammer, S., 1992).

The option chosen must also be compatible with existing processing systems.

The option chosen must also be compatible with existing processing systems, for example, waste combustion systems. When “wet” organics (food, grass, leaves, wet paper), in addition to recyclables, are separated from the waste stream, the remaining noncompostable, nonrecyclable fraction (sometimes referred to as “dry” waste) usually has a high Btu value and burns well in waste-to-energy (WTE) systems. Because yard trimmings have a high water content and should be separated from WTE feedstock, operating a yard trimmings composting program in conjunction with a WTE facility works well. Composting programs and incineration programs can also be mutually beneficial, as is the case in Dayton, Ohio, where a composting facility is located next door to an incinerator. If the incinerator is not operating, it may be possible to divert some of the organic matter to the composting facility. Likewise, if the composting facility receives a surplus of organic material that is also suitable for combustion, it may be diverted to the incinerator facility as a last resort.

Finally, if composting is chosen, some of the residual materials must be disposed of in a landfill. It is critical, therefore, that a landfill be considered as part of an overall plan in any composting program.

Communities should consider the following factors when deciding which composting method is most appropriate to meet their needs and goals (taken in part from Gould, et al., 1992):

- preferences of the community
- collection and processing costs
- residual waste disposal costs
- markets for the quality of compost produced
- markets for recyclables
- existing collection, processing and disposal systems.

Selecting Appropriate Technologies and Systems

Once a specific approach has been selected, program developers must choose technologies and equipment specific to that approach. The composting systems available may either be proprietary or generic, labor intensive or capital intensive. Several vendors have proven technologies to offer. In all cases, additional equipment and buildings may be needed that are not supplied by a single system supplier.

Selecting a vendor and a technology for composting early in the planning process is critical. Vendors interested in offering their technology should be asked to provide their qualifications, process technology, appropriate costs and references for consideration. Selection of a single system requires considerable engineering time to evaluate each vendors' qualifications; product design, ease of operation, and maintenance requirements; and the economics of each vendor's system as it relates to local conditions. Consultants should be part of the evaluation team if the community does not have in-house specialists to do the technical evaluation of the technologies under consideration. Hiring an outside professional may make the selection process more objective.

Experienced staff should be on the selection team.

Preliminary assessment of alternative technologies should be made to narrow the choice to a short list of vendors. A customized non-proprietary system may also be compared to the proprietary information provided by vendors. Engineers should work with equipment vendors to evaluate each technology. In addition, the collection system in use should be evaluated for its compatibility and cost, relative to the composting technology to be selected. At the same time, compost markets should be evaluated to determine the cost of developing a market.

A detailed technical discussion is provided for each of the composting approaches in the "Composting Approaches in Detail" section.

COMPOSTING TECHNOLOGIES

Technologies for composting can be classified into four general categories: windrow, aerated static pile, in-vessel composting, and anaerobic processing. Supporting technologies include sorting, screening, and curing. Several composting technologies are proprietary. Proprietary technologies may offer preprocessing and post-processing as a complete composting package. The technologies vary in the method of air supply, temperature control, mixing/turning of the material, and the time required for composting. Their capital and operating costs may vary as well.

Windrow Composting

A windrow is a pile, triangular in cross section, whose length exceeds its width and height. The width is usually about twice the height. The ideal pile height allows for a pile large enough to generate sufficient heat and maintain temperatures, yet small enough to allow oxygen to diffuse to the center of the pile. For most materials the ideal height is between 4 and 8 feet with a width from 14 to 16 feet.

Turning the pile re-introduces air into the pile and increases porosity so that efficient passive aeration from atmospheric air continues at all times. An example of a windrow composting operation is shown in Figure 7-2. As noted above, the windrow dimensions should allow conservation of the heat generated during the composting process and also allow air to diffuse to the deeper portions of the pile. The windrows must be placed on a firm surface so the piles can be easily turned. Piles may be turned as frequently as once per week, but more frequent turning may be necessary if high proportions of biosolids are present in the feedstock. Turning the piles also moves material from the pile's surface to the core of the windrow, where it can undergo composting.

Machines equipped with augers, paddles, or tines are used for turning the compost windrows.

Machines equipped with augers, paddles, or tines are used for turning the piles. Some windrow turners can supplement piles with water, if necessary. When piles are turned, heat is released as steam to the atmosphere. If inner portions of the pile have low levels of oxygen, odors may result when this portion of the pile is exposed to the atmosphere.

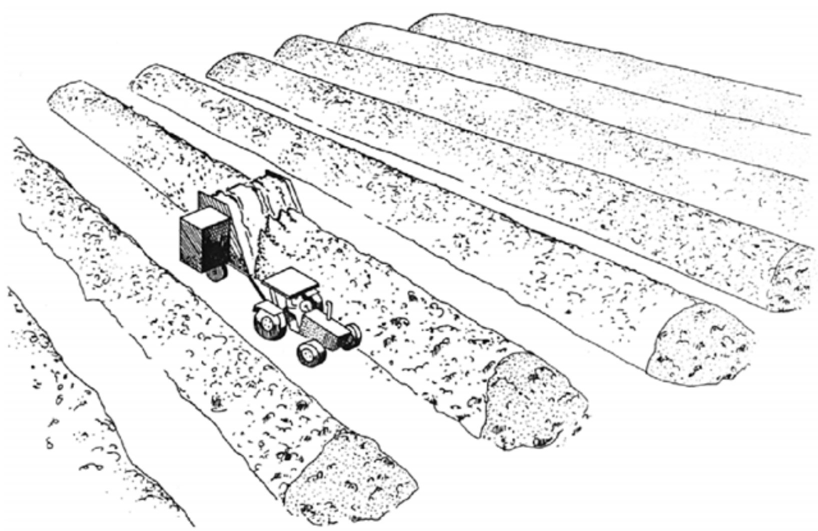
Equipment capacities and sizes must be coordinated with feedstock volume and the range of pile dimensions. Operations processing 2,000 to 3,000 cubic yards per year may find using front-end loaders to be more cost effective than procuring specialized turning equipment (Rynk et al., 1992).

Any leachate or runoff created must be collected and treated or added to a batch of incoming feedstock.

Piles may be placed under a roof or out-of-doors. Placing the piles out-of-doors, however, exposes them to precipitation, which can result in runoff or leachate. Piles with an initial moisture content within the optimum range have a reduced potential for producing leachate. The addition of moisture from precipitation, however, increases this potential. Any leachate or runoff created must be collected and treated or added to a batch of incoming feedstock to increase its moisture content. To avoid problems with leachate or runoff, piles can be placed under a roof, but doing so adds to the initial costs of the operation.

Figure 7-2

Windrow Composting with an Elevating Face Windrow Turner



Source: Reprinted with permission from Rynk, et al., *On Farm Composting Handbook, 1992* (NRAES-54)

Aerated Static Pile Composting

The piles are placed over a network of pipes connected to a blower, which supplies the air for composting.

Aerated static pile composting is a nonproprietary technology that requires the composting mixture (of preprocessed materials mixed with liquids) to be placed in piles that are mechanically aerated (see Figure 7-3). The piles are placed over a network of pipes connected to a blower, which supplies the air for composting. Air can be supplied under positive or negative pressure. When the composting process is nearly complete, the piles are broken up for the first time since their construction. The compost is then taken through a series of post-processing steps.

The air supply blower either forces air into the pile or draws air out of it. Forcing air into the pile generates a positive pressure system, while drawing air out of the pile creates negative pressure. The blowers are controlled by a timer or a temperature feedback system similar to a home thermostat. Air circulation in the compost piles provides the needed oxygen for the composting microbes and also prevents excessive heat buildup in the pile. Removing excess heat and water vapor cools the pile to maintain optimum temperatures for microbial activity. A controlled air supply enables construction of large piles, which decreases the need for land. Odors from the exhaust air could be substantial, but traps or filters can be used to control them.

The temperatures in the inner portions of a pile are usually adequate to destroy a significant number of the pathogens and weed seeds present. The surface of piles, however, may not reach the desired temperatures for destruction of pathogens because piles are not turned in the aerated static pile technology. This problem can be overcome by placing a layer of finished compost 6 to 12 inches thick over the compost pile. The outer layer of finished compost acts as an insulating blanket and helps maintain the desired temperatures for destruction of pathogens and weed seeds throughout the entire pile.

Aerated static pile composting requires less land than windrow composting.

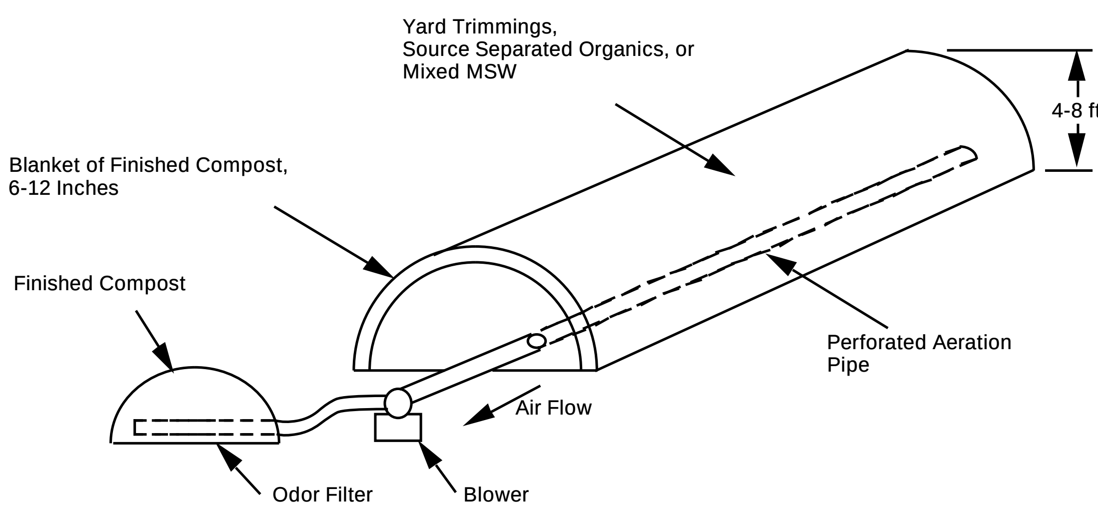
Aerated static pile composting systems have been used successfully for MSW, yard trimmings, biosolids, and industrial composting. It requires less land than windrow composting. Aerated static pile composting can also be done under a roof or in the open, but composting in the open has the same disadvantages as windrows placed in the open (see previous section on windrows). Producing compost using this technology usually takes 6 to 12 weeks. The land requirements for this method are lower than that of windrow composting.

In-Vessel Composting Systems

In-vessel composting systems enclose the feedstock in a chamber or vessel that provides adequate mixing, aeration, and moisture. There are several types of in-vessel systems available; most are proprietary. In-vessel systems vary in their requirements for preprocessing materials: some require minimal preprocessing, while others require extensive MSW preprocessing.

Drums, silos, digester bins, and tunnels are some of the common in-vessel type systems. These vessels can be single- or multi-compartment units. In some cases the vessel rotates, in others the vessel is stationary and a mixing/agitating mechanism moves the material around. Most in-vessel systems are continuous-feed systems, although some operate in a batch mode. All in-vessel systems require further composting (curing) after the material has been discharged from the vessel.

Figure 7-3
Aerated Static Pile for Composting MSW



Source: P. O'Leary, P. Walsh and A. Razvi, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course 1989-1990

All environmental conditions can be carefully controlled in an in-vessel system.

A major advantage of in-vessel systems is that all environmental conditions can be carefully controlled to allow rapid composting. The material to be composted is frequently turned and mixed to homogenize the compost and promote rapid oxygen transfer. Retention times range from less than one week to as long as four weeks. The vessels are usually placed in a building. These systems, if properly operated, produce minimal odors and little or no leachate.

In addition the air supply can be precisely controlled. Some units are equipped with oxygen sensors, and air is preferentially supplied to the oxygen-deficient portion of the vessel. In-vessel systems enable exhaust gases from the vessel to be captured and subjected to odor control and treatment.

Anaerobic Processing

Anaerobic processes have been used extensively for biologically stabilizing biosolids from municipal sewage treatment plants for many years. Research projects by Pfeffer and Liebman (1976), Wujcik and Jewell (1980), and more recently Kayhanian and Tchobanoglous (1992), and Richards et al. (1991) have demonstrated that similar biological processes can be used to stabilize municipal solid wastes. Several commercial systems have been developed and implemented to a limited extent.

Anaerobic systems generate sufficient energy to operate the process and have excess energy to sell.

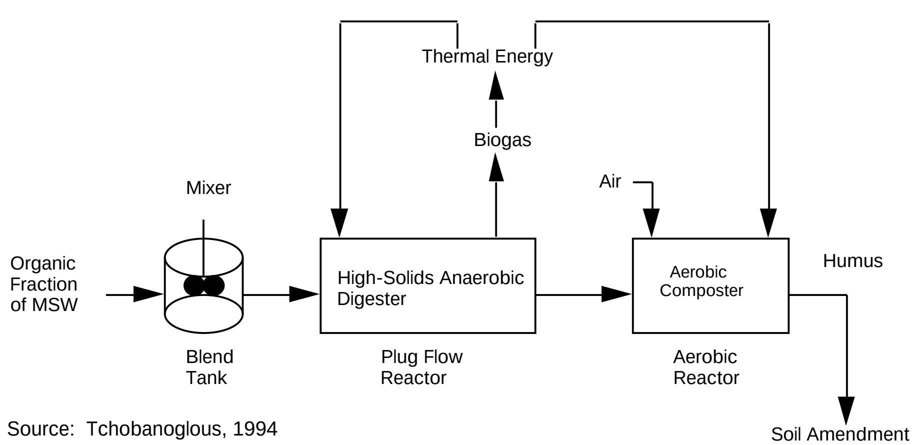
In anaerobic processes, facultative bacteria break down organic materials in the absence of oxygen and produce methane and carbon dioxide. Anaerobic systems, if configured efficiently, will generate sufficient energy in the form of methane to operate the process and have enough surplus to either market as gas or convert to electricity. Conventional composting systems, on the other hand, need significant electrical or mechanical energy inputs to aerate or turn piles.

Several approaches are available for anaerobic digestion of feedstocks. Single-stage digesters contain the entire process in one air-tight container. The feedstock is first shredded, and before being placed in the container, water and possibly nutrients are added to the previously shredded material. The single-stage digester may contain agitation equipment, which continuously stirs the liquified material. The amount of water added and the presence or absence of agitation equipment depends on the particular research demonstration or proprietary process employed.

Two-stage digestion involves circulating a liquid supernatant from a first-stage digester containing the materials to a second-stage digester (see Figure 7-4). This circulation eliminates the need for agitation equipment and also provides the system operator with more opportunity to carefully control the biological process.

Figure 7-4

Anaerobic Digester with Aerobic Compost Curing



Source: Tchobanoglous, 1994

As digestion progresses, a mixture of methane and carbon dioxide is produced. These gases are continuously removed from both first- and second-stage digesters and are either combusted on-site or directed to off-site gas consumers. A portion of the recovered gas may be converted to thermal energy by combustion which is then used to heat the digester.

A stabilized residue remains when the digestion process is completed. The residue is either removed from the digester with the mechanical equipment, or pumped out as a liquid. The residue is chemically similar to compost but contains much more moisture. Conventional dewatering equipment can reduce the moisture content enough to handle the residue as a solid. The digested residue may require further curing by windrow or static pile composting.

Screening

Compost is screened to meet market specifications.

Compost is screened to meet market specifications. Sometimes this processing is done before the compost is cured. One or two screening steps and possibly additional grinding are used to prepare the compost for markets. Screens are used to separate out the compost from the noncompostable fraction. During the composting operation, the compostable fraction undergoes a significant size reduction. The noncompostable fraction undergoes little or no size reduction while being composted. This helps to screen the noncompostable fraction from the compost. Depending on the initial shredding process and the size of screen used, some larger compostable particles may enter the noncompostable stream during screening. One or more screens may be used with the usual configuration being a coarse screening followed by a fine screening step. Screening can be done before or after the curing process. The noncompostable fraction retained on the coarse screen is sent to the landfill. Compostable materials retained on finer screens may be returned to the beginning of the composting process to allow further composting.

The moisture content of the compost being screened should be below 40 percent.

For screening to successfully remove foreign matter and recover as much of the compost as possible, the moisture content of the compost being screened should be below 50 percent. Drying should be allowed only after the compost has sufficiently cured. If screening takes place before curing is complete, moisture addition may be necessary to cure the compost. The screen size used is determined by market specifications of particle size.

The screened compost may contain inert particles such as glass or plastics that may have passed through the screen. The amount of such inert materials depends on feedstock processing before composting and the composting technology used. Sometimes, screening alone is not adequate to remove all foreign matter. This may result in diminished market acceptance of the product.

Curing

By the end of the rapid phase of composting, whether in windrows, aerated static pile, in-vessel, or anaerobic digestion, a significant proportion of the easily degradable organic material has been decomposed and a significant amount of weight has been lost. Organic materials remaining after the first phase decompose slowly. Microbial activity, therefore, continues at a much slower rate, despite ideal environmental conditions. The second phase, which is usually carried out in windrows, usually takes several weeks to six months, depending on outdoor temperatures, the intensity of management, and market specifications for maturity. With some system configurations, a screening step may precede the curing operation.

Cooling indicates reduced microbial activity and may occur before curing is complete.

During curing the compost becomes biologically stable, with microbial activity occurring at a slower rate than during actual composting. Curing piles may either be force-aerated or use passive aeration with occasional turning. As the pile cures, less heat is generated by the microorganisms and the pile begins to cool. When the piles cool, it does not always mean that the curing is complete. Cooling is a sign of reduced microbial activity, which can result from a lack of moisture, inadequate oxygen within the pile, a nutrient imbalance, or the desired result—completing the compositng process. Curing may take from a few days to several months. The cured compost is then prepared for markets.

MARKETING COMPOSTS

A well-planned marketing approach ensures that all the compost will be distributed.

The final use of the compost product and its potential markets are crucial issues that must be addressed early in the planning stages of the compost program and facility. A well-planned approach ensures that all the compost will be distributed; accomplishing this goal, however, requires producing a consistently high-quality compost in order to satisfy the needs of most markets.

A number of state regulatory agencies are considering regulating compost. They usually consider a variety of approaches for regulating the land application of municipal solid waste compost. One possible approach is to rely on the federal standards for land application of biosolids to establish a framework within which to derive the state MSW compost spreading standards. An important consideration is the metals content of the applied material. Table 7-2 shows the maximum metals content for land application of biosolids. A protocol is provided to limit the maximum cumulative amount of metals in biosolids that may be spread on a particular site. If a biosolid has metal content that is less than shown in Table 7-2, the sludge may be sold or given away provided that specified annual cumulative rates for the same list of metals is not exceeded. The federal standards for the use and disposal of biosolids are contained in 40 CFR Part 503.

Table 7-2
Ceiling Concentrations for Biosolids

Pollutant	Concentrations (mg/kg)*
Arsenic	75
Cadmium	85
Chromium	3000
Copper	4300
Lead	840
Mercury	57
Molybdenum	75
Nickel	420
Selenium	100
Zinc	7500

*Dry weight basis

Source: USEPA, 1994

There is limited regulation of properly processed yard trimmings compost. Where state guidelines do exist, the parameters of interest are often associated with measuring the completeness of the composting process. The land spreading operations are monitored to insure that the yard trimmings compost is being spread, not dumped into piles.

The available nitrogen content of the compost and the soil may be a determining factor for deciding the allowable amount of compost that may be spread onto agricultural land. With biosolids applications, the allowable amount is determined by crop uptake. Similar approaches have been used to establish compost application levels.

Marketing Strategies

Quality and composition factors specific to the targeted markets must be carefully assessed.

In marketing composts, there are no set guidelines that apply to all composting facilities—every facility and the markets it seeks to serve are somewhat different. Factors specific to the targeted markets must be carefully assessed. The quality and composition required for a compost product to meet the needs of a specific market depend on a mix of factors, including the intended use of the product, local climatic conditions, and even social and cultural factors. The criteria that best fit the specific market should be incorporated in the marketing plan. For example, meeting the needs of agricultural applications requires minimizing the potential uptake of metal contaminants and the presence of glass and plastic, and satisfying other feed / food safety concerns. Satisfying the needs of horticultural nurseries requires ensuring the maturity of the compost, pH, nutrient content, soluble salts, particle size, shrinkage, and moisture-holding potential (Buhr, et. al. 1993).

Marketing efforts should be continuous—before, during, and after the compost production. Two major objectives should guide marketing plans: One is selling or otherwise distributing all of the compost that is produced. The second is optimizing revenues and minimizing costs.

Market developers should also be aware of potential large-scale users of composts and consider targeting such users in their areas or regions. Potential large-scale users include the following (LaGasse, 1992):

Consider targeting large-scale users.

- farms
- landscape contractors
- highway departments
- sports facilities
- parks
- golf courses
- office parks
- home builders
- cemeteries
- nurseries
- growers of greenhouse crops
- manufacturers of topsoil
- land reclamation contractors.

Adopting the right marketing attitude is also critical. Compost should be viewed as a usable product—not a waste requiring disposal. Composting should be portrayed as an environmentally sound and beneficial means of recycling organic materials rather than a disposal method for solid wastes.

Education, Research, and Public Relations

Marketers must thoroughly understand the advantages and limitations of a given compost.

Marketers must thoroughly understand the advantages and limitations of a given compost for a given use. Based on its advantages and limitations, the compost's value to the user should be a focus of the marketing strategy. To attract potential customers who have successfully used other soil amendments, marketers should design an education program focusing on the qualities of the specific compost products and how they can meet customer needs. The challenge is to convince potential customers that there is a compost product to meet specific needs.

A successful marketing program should focus on what the compost can and cannot do. Marketers should emphasize any testing programs that are applicable and uses that are compatible with the compost. Give users specific instructions; they may not have used your compost or a similar product before. If the compost is sold in bags, their labels should describe the contents, its potential uses, any precautions / warnings, and how to use the material. Provide bulk users with written instructions for using and storing the compost.

Potential Compost Uses

A study conducted by the Composting Council (Buhr, et. al.) identified nine major potential markets for compost in the U.S.; these include the following:

- landscaping
- topsoil
- bagged for retail consumer use (residential)
- surface mine reclamation (active and abandoned mines)
- nurseries (both container and field)
- sod
- silviculture (Christmas trees, reforested areas, timber stand improvement)
- agriculture (harvested cropland, pasture / grazing land, cover crops).

The leading markets are agriculture, silviculture (trees grown for harvest), and sod production (Buhr, et al.). Some of these major markets have several different potential compost applications. In agriculture, for example, compost can be used as a soil conditioner, fertilizer, and for erosion control and plant disease suppression. In the residential retail market, compost can be used as potting soil, topsoil, mulch and in soil amendments (Buhr, et al. or Slivka, et al.). Compost is also used as a soil amendment to establish vegetation on disturbed lands (for example at mining sites).

Knowing the many potential uses of a compost is required for targeting appropriate markets.

Knowing the many potential uses of compost is an important prerequisite for targeting appropriate markets. Table 7-3 lists compost markets and specific uses for different types of compost. In evaluating potential uses, however, marketers should also recognize the practical limitations of some applications.

Traditionally, the role of compost as a soil additive / soil conditioner has been widely recognized. As a conditioner composts can do the following:

- improve water drainage
- increase water-holding capacity
- improve nutrient-holding capacity
- act as pH buffering agent
- help regulate temperature
- aid in erosion control
- aid air circulation by increasing the void space
- improve the soil's organic matter content
- aid in disease suppression
- slowly release nutrients into the soil
- correct deficiencies in minor elements
- reduce bulk density
- increase cation exchange capacity of sandy soils.

Composts are a good source of plant nutrients and in some applications may have advantages over fertilizers.

Composts are also a good source of plant nutrients and in some applications may have advantages over fertilizers. For example, the plant nutrients in composts, unlike fertilizers, are released over an extended period of time. In addition, composts supply important micronutrients that fertilizers lack. On the other hand, composts supply fewer amounts of macronutrients than fertilizers.

Certain types of composts can successfully control soil-borne diseases, particularly for container crops. A number of research studies have demonstrated that stable composts made from bark and other materials can be effective in suppressing diseases such as *Pythium* and *Phytophthora* (Hoitink, Boehm and Hadar, 1993; Logsdon, 1989). The disease-controlling qualities of the compost result mainly from the presence of beneficial microorganisms that are antagonists of plant pathogens. Composts from tree barks have been used successfully, and tests are being done with composts made from other materials. The use of composts specifically for suppressing disease have been limited primarily to nursery operators. Technology needs to be developed to manufacture products with defined and consistent properties for use with vegetable and agronomic crops.

Table 7-3

Potential Users of and Uses for Compost

User Group	Primary Uses for Compost Products	Compost Products	Packaging
Agricultural and Residential Users			
Forage and field crop growers	Soil amendment, fertilizer supplement, top dressing for pasture and hay crop maintenance	Unscreened and screened compost	Bulk
Fruit and vegetable farmers	Soil amendment, fertilizer supplement, mulch for fruit trees	Unscreened and screened compost	Bulk
Homeowners	Soil amendment, mulch, fertilizer supplement, and fertilizer replacement for home gardens and lawns	Screened compost, high-nutrient compost, mulch	Primarily bags, small-volume bulk
Organic farmers	Fertilizer substitute, soil amendment	Unscreened and screened compost, high-nutrient compost	Primarily bulk
Turf growers	Soil amendment for establishing turf, top dressing	Screened compost, topsoil blend	Bulk
Commercial Users			
Cemeteries	Top dressing for turf, soil amendment for establishing turf and landscape plantings	Screened compost	Bulk
Discount stores, supermarkets	Resale to homeowners	General screened compost product	Bags
Garden centers, hardware/lumber outlets	Resale to homeowners and small-volume users	Screened compost, mulch	Primarily bags, small-volume bulk
Golf courses	Top dressing for turf, soil amendment for greens and tee construction, landscape plantings	Screened compost, topsoil blend	Bulk
Greenhouses	Potting mix component, peat substitute, soil amendment for beds	High-quality, dry, screened compost	Bulk and bag
Land-reclamation contractors	Topsoil and soil amendment for disturbed landscapes (mines, urban renovation)	Unscreened compost, topsoil blend	Bulk
Landscapers and land developers	Topsoil substitute, mulch, soil amendment, fertilizer supplement	Screened compost, topsoil blend, mulch	Bulk
Nurseries	Soil amendment and soil replacement for field-grown stock, mulch, container mix component, resale to retail and landscape clients	Unscreened and screened compost, composted bark, mulch	Primarily bulk, some bags
Municipal Users			
Landfills	Landfill cover material, primarily final cover	Unscreened low-quality compost	Bulk
Public works departments	Topsoil for road and construction work, soil amendment and mulch for landscape plantings	Unscreened and screened compost, topsoil blend	Bulk
Schools, park and recreation departments	Topsoil, top dressing for turf and ball fields, soil amendment and mulch for landscape plantings	Screened compost, topsoil blend, mulch	Bulk

Source: Reprinted with permission from Rynk, et al., *On-Farm Composting Handbook, 1992* (NRAES-54)

Compost Quality—Impacts on Uses and Markets

The quality of a particular compost product and the consistency with which that quality is maintained directly impact the product's marketability. Table 7-4 summarizes compost quality guidelines based on end use of the compost. Quality is judged primarily on particle size, pH; soluble salts, stability, and the

Table 7-4

Examples of Compost Quality Guidelines Based on End Use*

	End Use of Compost			
	Potting Grade	Potting Media Amendment Grade (a)	Top Dressing Grade	Soil Amendment Grade (a)
Recommended Uses:	As a growing medium without additional blending	For formulating growing media for potted crops with a pH below 7.2	Primarily for top-dressing turf	Improving agricultural soils, restoring disturbed soils, establishing and maintaining landscape plantings with pH requirements below 7.2
Characteristic				
Color:	Dark brown to black	Dark brown to black	Dark brown to black	Dark brown to black
Odor:	Should have good, earthy odor	Should have no objectionable odor	Should have no objectionable odor	Should have no objectionable odor
Particle Size:	Less than 1/2 inch (13 mm)	Less than 1/2 inch (13 mm)	Less than 1/4 inch (7 mm)	Less than 1/2 inch (13 mm)
pH:	5.0–7.6	Range should be identified	Range should be identified	Range should be identified
Soluble Salt Concentration: (mmhos per cm)	Less than 2.5	Less than 6	Less than 5	Less than 20
Foreign Materials:	Should not contain more than 1% by dry weight of combined glass, plastic, and other foreign particles 1/8–1/2 inch (3–13 cm)	Should not contain more than 1% by dry weight of combined glass, plastic, and other foreign particles 1/8–1/2 inch (3–13 cm)	Should not contain more than 1% by dry weight of combined glass, plastic, and other foreign particles 1/8–1/2 inch (3–13 cm)	Should not contain more than 5% by dry weight of combined glass, plastic, and other foreign particles
Heavy Metals:	Should not exceed EPA standards for unrestricted use (c)	Should not exceed EPA standards for unrestricted use (c)	Should not exceed EPA standards for unrestricted use (c)	Should not exceed EPA standards for unrestricted use (c)
Respiration Rate: (mg per kg per hour) (b)	Less than 200	Less than 200	Less than 200	Less than 400

* These suggested guidelines have received support from producers of horticultural crops.

(a) For crops requiring a pH of 6.5 or greater, use lime-fortified product. Lime-fortified soil amendment grade should have a soluble salt concentration less than 30 mmhos per centimeter.

(b) Respiration rate is measured by the rate of oxygen consumed. It is an indication of compost stability.

(c) These are EPA 40 CFR Part 503 standards for sewage biosolids compost. Although they are not applicable to MSW compost, they can be used as a benchmark.

Sources: Reprinted with permission from Rynk, et al., *On Farm Composting Handbook, 1992* (NRAES-54); and USEPA, 1994

Many markets will also look at the uniformity of the product for assessing quality.

presence of undesirable components such as weed seeds, heavy metals, phytotoxic compounds, and undesirable materials, such as plastic and glass. Many markets will also look at the uniformity of the product from batch to batch and sources of the raw materials used to make it. Quality and consistency become more important when compost is used for high-value crops such as potted plants and food, when it is applied to sensitive young seedlings, and when it is used alone, without soil or other additives. Tolerance levels for factors such as particle size, soluble salt concentrations, foreign inert materials, and stability are usually higher when compost is used as a soil amendment for agricultural land, restoration of disturbed soils, or other similar uses.

Concentrations of heavy metals and PCBs will make marketing a compost difficult.

Concentrations of heavy metals and PCBs that exceed USEPA or state standards for unrestricted use will make compost marketing considerably more difficult or even impossible to undertake. Although regulations differ among states, composts are generally classified according to concentrations of certain pollutants such as heavy metals and PCBs. Markets buying or accepting composts that exceed government standards for unrestricted use often have to limit the application rates or cumulative amount applied. Because heavy metals and PCBs pose dangers to human and animal health, these markets may also have to keep written records, apply for special land-spreading permits, and follow specific management practices such as soil incorporation or observe a waiting period before grazing is allowed.

Composting facility operators can increase the marketability of their composts by selectively accepting feedstock materials. Raw materials used in the composting process influence the physical and chemical properties of the compost. Clean, source-separated materials are sometimes preferred as feedstocks over mixed solid waste, particularly when used for high-value crops or retail sale. Facilities designed to accept MSW as a feedstock often have less control over the materials they receive. Table 7-5 lists common sources of chemical contaminants in MSW. A front-end processing system that effectively removes contaminants and a permanent household hazardous waste disposal program serving generators may help improve the quality of MSW compost.

Table 7-5
Common Sources of Contaminants in MSW

Batteries
Consumer electronics
Motor oil
Solvents
Cleaning products
Automotive products
Paints and varnishes
Cosmetics

Source: USEPA, 1994

Compost quality is also affected by the aging process and storage conditions.

Compost quality is also affected by the aging process and storage conditions. Compost that has cured for 3 to 4 months will typically have a finer texture and a lower pH. In addition, most of the nitrogen available in compost converts from ammonium-nitrogen to nitrate-nitrogen during that time period. High concentrations of ammonium-nitrogen can cause temporary stunting and burning of the foliage of sensitive species. Storage methods can impact quality because finished compost continues to slowly biodegrade until all sources of available carbon are depleted. Compost should be stored in a dry location and in sufficiently small piles to allow aerobic respiration to continue. Without enough air, compost will become anaerobic and develop odors, alcohols, and organic acids that are damaging to plants.

Compost markets and end uses dictate what types of tests are necessary and how frequent they should be made.

The quality of a compost can be measured through periodic testing. Compost markets and end uses usually dictate what types of tests are necessary and the frequency for conducting them. Federal and state environmental regulations require specific tests for composts made from mixed solid waste, biosolids, and certain source-separated commercial and industrial wastes. Regular testing is essential for producing a quality product on a consistent basis. Some of routine tests for composts include moisture content, density, pH, soluble salts, particle size, organic matter content, carbon:nitrogen ratio and level of foreign inerts e.g., glass, plastics. Many independent and state-operated labs also conduct tests for micro-nutrients, respiration rate, heavy metals, pathogen levels, and chemical contaminants. A few labs can perform tests specifically for compost maturity or phytotoxicity. Compost maturity can be defined as the degree of decomposition of organic matter during composting. Definitions of maturity are based on the potential uses of the compost (Chen and Inbar, 1993). A number of analytical methods are used to determine compost maturity, but no single method has yet been identified as consistently reliable. Many researchers and compost facility operators are using a combination of tests to determine maturity. Some of the methods being used include bioassays, starch content, cation exchange capacity, concentration of humic substances, cellulose content, carbon:nitrogen ratio, carbon:nitrogen ratio in water extracts of composts, respiration rate, and spectroscopic analyses (Chen and Inbar, 1993; Inbar et al., 1990).

Compost maturity is an important quality measure.

Quality Control

Whatever goes in as compost feedstock will be reflected in the compost produced. Because changes in the compost feedstock also change the compost quality, feedstock material should be carefully controlled to ensure consistent compost quality. This may mean that some noncompostable materials should be rejected at the compost site if the product from these materials will be difficult or impossible to market. If accepted, attempts should be made to segregate these feedstocks and market the resulting compost separately.

The compost feedstock affects product quality.

The compost should be of a consistent quality. This is important to all sectors of the market, but especially to repeat customers who expect a certain quality product. This may not be as important to the one-time buyer. However, if the quality of the compost is good, the one-time buyer could become a repeat customer. The marketer must understand the risk that some users (businesses) may be taking if product quality is unreliable. In addition, if some composts are extremely poor in quality, customers' confidence in all composts may be reduced. Quality control assurances for consistently producing a high-quality compost are a necessity for compost marketing.

Facility managers should establish a testing program backed by minimum quality standards. Tolerances for quality variations should be set and adhered to. Managers should stand behind their products and address customer complaints by promptly taking corrective action. Maintaining a high degree of credibility and integrity is essential.

Manufacturing Multiple Products

A successful marketing strategy should include the ability to offer more than one grade of product. Such a strategy could increase the revenues earned and the amount of compost sold. This could also alleviate some of the peak demand periods, improve distribution, and require less storage space.

Being able to make different products is a good marketing strategy.

Most composting facilities attempt to make one compost from a mixture of a variety of feedstock types. To meet the needs of specific customers, consider segregating a portion or portions of the feedstocks to produce composts that are significantly different in chemical, physical, or biological properties. Different grades of compost can also be made from a single feedstock. For example, the compost could be supplemented with plant nutrients to enhance the nutrient properties. The pH of the compost can be adjusted to suit different plant needs. Composts can be mixed with different mineral or organic materials to produce potting soil mixes. Varying the particle size by using coarser or finer screens produces a rough-grade and a fine-grade compost respectively.

Inventorying Potential Markets

Who are the potential users of the compost? What are they currently using? Can the compost be a satisfactory substitute for products currently being

Marketers should determine if there are potential users who could benefit from their product.

used? Marketers should determine if there are users who could benefit from using the compost, especially those who have not considered using compost in the past. The marketing plan should include an inventory of those users and marketers should focus on the innovators, those entrepreneurs who are looking for alternatives that can lower their costs. The goal is to develop target markets and focus on them.

Municipalities that manufacture composts should look at in-house markets. Determine the annual dollars spent on fertilizers, topsoil and other soil amendments used by governmental units in the region. Can the compost serve as a substitute for these products? A fair amount of demand can often be created within the municipality.

Marketers should try to project the total demand for compost in a given market and relate this to the production capacity of the composting facility. They should determine the demand pattern through the year. Is the peak demand seasonal? If the demand is seasonal, plans for storing the compost at the site or at the buyer's location should be made. Compromises in price may have to be made if the compost has to be purchased and stored by the user. Who provides the transportation? Unless properly planned, transportation could be a bottleneck in meeting buyer's needs on time. This could jeopardize credibility of the marketing program.

What products, if any, are competing with the compost? Marketers should answer this question and stress the positive characteristics of the compost as a substitute for peat in potting soil mixes, for fertilizer, and for pine bark or peat in landscaping.

Distributing Compost

While many municipalities choose to market their own products, others rely on private marketing firms that specialize in marketing composts and related products. It may be appropriate to take the former approach if a small quantity of compost is produced, although some large facilities market their own compost. The self-marketing approach adds administrative costs and may require personnel with special expertise in marketing.

Compost distribution is an important consideration.

Marketing firms offer many advantages. They may be able to do more if they are serving more than one community by using the resources available to them in a more efficient manner. Private marketers can also expand the range of publicity and advertising by attending trade shows, field demonstration days, etc. They can also develop professional public relations campaigns, suggest appropriate equipment for handling the compost, and competitively price the compost. While all of these functions can be performed by a municipality as well, doing so puts a significant burden on the resources available.

One method of distribution adopted by some facilities that compost yard trimmings is to rely on home owners to remove the compost from the compost site by bagging their own. This approach has been successful for some communities. Most home owners want good-quality compost in small quantities, and many prefer to purchase it already bagged because they lack containers or the means to transport loose compost. Bagging composts, however, requires additional investment in capital and manufacturing costs. If the compost is bagged, it should be sold through local retail outlets. A successful marketing program for bagged compost requires intensive advertising and a good-quality product. This marketing approach is likely to return a greater amount of revenues as well.

Pricing

Pricing any product depends on supply and demand, the price structure of competing products, the quality of the product, transportation costs, production costs, research and development costs, marketing costs, the volume of material purchased by a single customer. The pricing structure should be individually established for each composting operation.

The goal of marketing should be to sell all the compost that has been produced. The price of the compost should facilitate this goal. Revenues alone should not be expected to offset the cost of producing the compost, but prices should be set to offset as much of the production costs as possible.

Decide early on a pricing strategy.

Price the product modestly at first, then increase the price based on demand. If the compost is given away for free, the user attaches very little value to it. Pricing should be adjusted based on quantity purchased, and large volume buyers should get a significant discount.

One of the most sensitive factors in pricing and marketing compost is the cost of transportation. Compost is bulky and bulky products can be very expensive to transport. Transportation costs must be carefully evaluated while the facility is being planned, and the distance between potential markets and the manufacturing facility should be minimized.

First-time users of the compost should be charged for the compost or its transportation. This helps customers see compost as a valuable product. Moreover, if customers like the compost, they will be willing to pay for the next shipment.

Compost can be sold at lower prices during low-demand periods. Doing so means the manufacturer does not have to use up valuable storage space. It also helps the users because they will have the compost when they are ready to use it.

Finalizing Market Arrangements

A composting program's ultimate success depends on the marketing arrangements for the processed products. A technical evaluation conducted during the planning stages should provide quantity and quality data, which can be used to finalize marketing agreements.

Both formal and informal contracts have advantages.

Contracts between compost facility operators and product buyers will state the quality specifications, price, quantity, delivery arrangements, use restrictions, and payment procedures. All legal contracts should be reviewed by an attorney.

Most contracts are made with large-quantity buyers. If compost is to be supplied to a large number of small users, contract agreements may be less formal. The agreement must at least specify the minimum quantity and how the compost will be used.

Informal contracts are probably more appropriate when the compost is being given away. Nevertheless, the informal contract is an important communication vehicle.

COMPOSTING APPROACHES IN DETAIL

Composting options available to communities range from the low-capital-investment methods of backyard residential composting to the more capital-intensive mixed municipal solid waste composting, requiring advanced-teaching high-technology processing plants. Each approach has specific benefits and limitations. The approach or mix of approaches that a community chooses depends on that community's characteristics and particular needs.

Grasscycling

During the growing season, 30 or more percent of the MSW generated in some communities is yard trimmings. An aggressive program of "grasscycling" can significantly reduce the amount of yard trimmings and, hence, the need for processing and disposing of those materials.

Grasscycling can significantly reduce the amount of yard trimmings in the waste stream.

Grasscycling is the natural recycling of grass clippings by leaving the clippings on the lawn after mowing (see Figure 7-5). Contrary to widely accepted misconceptions, leaving grass clippings on a lawn after mowing is not

Most residents need to be told of the benefits of grasscycling.

detrimental to maintaining a good lawn if several simple guidelines are followed. Studies have shown that total lawn maintenance time is reduced when clippings are mulched and left on the lawn, despite the fact that the lawn may need to be mowed slightly more often. For example, a Texas study (Knoop and Whitney, 1993) found that grasscycling reduced lawn maintenance time by 38 percent. In addition, leaving grass clippings on the lawn reduces the need to fertilize by 25 to 33 percent, because nutrients in the grass clippings are simply being recycled. A 25 to 33 percent fertilizer savings can normally be achieved. In addition, grasscycling reduces or eliminates costs for disposal bags and possibly pick-up service charges are eliminated.

When establishing a grasscycling program, residents should be told about the benefits described above and how to best maintain grass so that clippings can be left on the lawn. Turf management experts recommend cutting when the grass is dry. A maximum of one inch should be removed during each mowing and no more than one-third of the length should be removed. U.S. Department of Agriculture studies have shown that when these cutting guidelines are followed thatch does not build up in the lawn. If grass is not wet most lawn mowers can cut it into small enough pieces so that the clippings will simply be recycled into the lawn. Simple attachments are also available for converting standard mowers into mulching mowers.

The key to a successful grasscycling program is public education. To build awareness, support, and participation, the cooperation of lawn and garden supply stores and other businesses that provide lawn maintenance equipment and supplies should be sought. Such businesses can post announcements and distribute informational materials to their customers. Government agencies, such as the local parks department, can serve as a good example. To help residents overcome skepticism, demonstration plots can be established in high-visibility locations. All recommendations should accurately reflect local growing conditions and address any concerns that residents may have.

More information is rapidly becoming available about successful grasscycling programs. Detailed information is available from the American Horticultural Society in Alexandria, Virginia.

Figure 7-5

Grass Being Mowed and Returned to the Lawn for Grasscycling

Source: University of Wisconsin–Madison Solid and Hazardous Waste Education Center, 1994

Backyard Residential Composting

Many communities have established programs to encourage residents to compost yard trimmings and possibly other organic materials in compost piles or containers located on their property.

Process Description

Simply constructed boxes make a residential compost pile easy to set up and maintain.

Yard trimmings, which include grass clippings, leaves, garden materials, and small twigs, are ideally suited for composting. Although materials can be composted in a small heap, simply constructed boxes can make a residential compost pile easier to set up and maintain. Figure 7-6 shows several yard trimmings composting containers. Waste is placed in the containers to a depth of about four feet and turned every few weeks or months. Depending on weather conditions, the addition of water may be necessary. Aerobic conditions are generally sustained, and decomposition is faster than would naturally occur if the yard trimmings were left on the ground. As decomposition takes place, the frequency of turning can be reduced to every few months. Significant settling will occur as compost is formed. Complete stabilization and production of finished compost can take from four months to two years with longer times being associated with colder climates and little or no turning. Residents can produce compost at a higher rate by more frequently stirring the contents and moving the material through a series of containers. More detailed information about grasscycling is available in "Composting to Reduce the Waste Stream" (1991).

Implementation

An effective educational program and appropriate incentives must be provided to successfully implement on a community-wide basis. Chapter 1, "Public Education and Involvement," deals in depth with public education programs and readers are encouraged to review it along with the information provided below.

Public Education

The education program must describe how to do backyard composting and its benefits.

Developing a backyard composting program begins with an awareness program explaining why backyard composting is needed and providing information about various options and methods. More detailed information is then presented to encourage participation. Once backyard composting has been adopted, a continuing community relations program must report benefits, answer questions or concerns, inform new or nonparticipating residents, and encourage ongoing composting activities.

Some communities have found that working through schools or community groups can facilitate implementation of backyard composting. These groups provide a forum establishing communication channels. Some of these groups are already committed to environmental improvement as part of their mission. A variety of manuals have been prepared for backyard composting education programs. Contact your state's environmental agency or your local solid waste program for such publications.

Financial Support

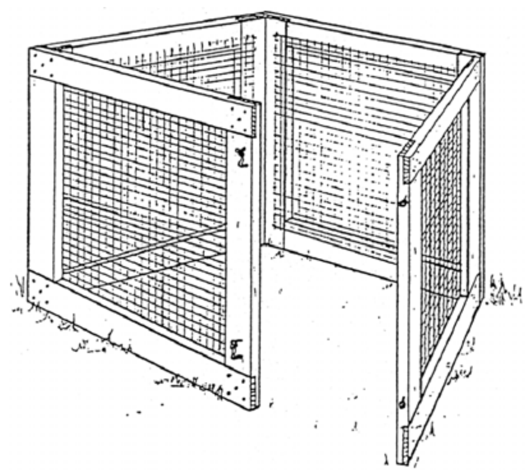
A community that is serious about implementing backyard composting as part of an integrated solid waste management program must appropriately support the program. Backyard composting can divert significant quantities of organic material and save money that otherwise would be spent on waste collection, processing, or disposal. Consequently, allocating funds to support a backyard composting program can prove cost-effective. In addition, diverting yard trimmings from the MSW stream can save landfill space.

Figure 7-6
Yard Trimmings Composting Units

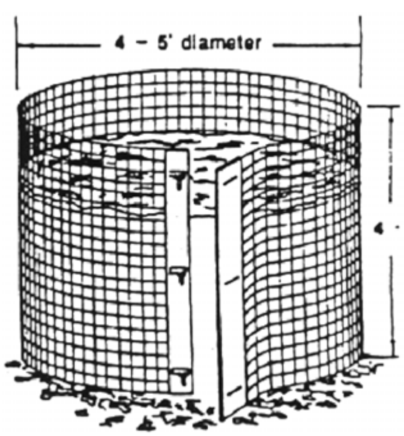
Residential Yard Trimmings Composting

- Holding units like these are used for composting yard trimmings and are the least labor- and time-consuming ways for residents to compost. Some units are portable and can be moved to the most convenient location. Non-woody yard materials are best to use. As you collect weeds, grass clippings, flowers, leaves and harvest remains throughout the year, place them in the bins.
- It can take four to six months or as long as two years to produce a good-quality compost using such units. Chopping or shredding the materials, mixing in high-carbon and high-nitrogen materials, and providing adequate moisture and aeration speeds the process.
- Sod can also be composted, with or without a composting structure, by piling it upside down (roots up, grass down), providing adequate moisture, and covering it with black plastic to eliminate light.
- Leaf mold can be made by placing autumn leaves in a holding unit for a year or more.
- Holding units can be constructed from circles of wire fencing, from old wooden pallets, or from wood and wire.
- Backyard composting of food scraps is regulated or prohibited in some communities. Residents should check with their local and state environmental agencies before attempting to compost food scraps.

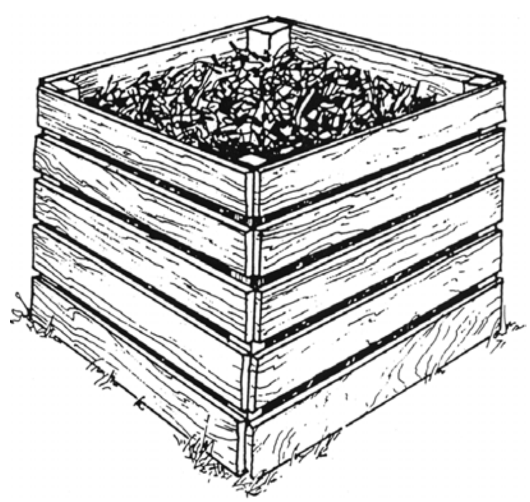
A. Portable Wood and Wire Unit



B. Wire Bin



C. Wooden-Pallet Unit
(Made from wooden pallets or pressure-treated lumber)



Sources: *Home Composting Handbook* 1992. A and B Reproduced by permission of the Seattle Engineering Department's Solid Waste Utility and the Seattle Tilth Association, Seattle, WA; C reprinted with permission from *Composting to Reduce the Waste Stream* (NRAES-43), N.E. Regional Agricultural Engineering Service, Cooperative Extension, Ithaca, NY 14853, 1991

Communities will need to provide financial support for public education programs. In addition, to further encourage participation, some communities have provided containers for composting. This represents a nominal per-household cost.

Financial incentives may be needed.

Some communities also provide incentives to encourage backyard composting or reduction in the generation of yard trimmings. For example, the City of Seattle allows home owners who do not generate yard trimmings to avoid paying a $2-per-month fee for yard trimmings pickup. Likewise, some communities charge for yard trimmings pickup separately, often by the bag, in an effort to induce home owners to reduce the quantity of yard trimmings produced.

Yard Trimmings Composting Programs

Composting yard trimmings is another very effective means of diverting significant quantities of materials from land disposal facilities. The challenge lies in managing the yard trimmings stream and the composting process in the most economic, nuisance-free manner. This challenge is formidable, since new material management techniques often require individual residents to do more than simply put bags of waste at the curb and may require communities to devise methods of handling materials that have already begun to decompose by the time they are picked up or delivered to a composting facility. Unless the benefits of composting are carefully explained to a community's residents, intense opposition to even the best-designed program can occur.

Off-site composting of yard trimmings is another alternative.

Grass and leaves make up the bulk of yard trimmings produced. Other materials include tree limbs, trunks and brush; garden materials such as weeds and pine needles; and Christmas trees.

Different types of yard trimmings decompose at a different rates and mixing them can affect the quality, marketability, and composting time of the finished product. To maximize system efficiency, it may be better to determine separately the proper handling method for each type of material. For example, rather than composting woody materials such as trees and brush, these materials may be better handled by chipping for the purpose of producing mulch. Wood chips are often in demand for use in community parks or highway projects. Likewise, tree trunks or large limbs can be cut and used as firewood.

Collection

Obviously, the most expedient and cost-effective option is *not* to collect yard trimmings in the first place. And for an increasing number of communities and states, barring or restricting the collection and disposal of yard trimmings is the option of choice. For many rural communities, a prohibition on disposing of yard trimmings at the local landfill can significantly reduce land disposal quantities. Refusing to accept yard trimmings may be enough of an incentive for local residents to change their habit of collecting and bagging leaves and grass.

Drop-Off Sites

For more urbanized communities, however, the "no collection" approach may create problems. For example, piles of leaves and grass may begin to show up in ditches and in open areas, where they pose local eyesores or nuisances. People may rake yard trimmings into roadways, creating transportation hazards, blocking sewer systems, or polluting local lakes and streams. For small or medium-sized communities, establishing a drop-off site may be the preferred method of collecting yard trimmings. Establishing a drop-off site allows a community to avoid yard trimmings collection costs by requiring that residents deliver the waste to a designated site. The site can be the compost facility or, for a larger community, a drop-off point where yard trimmings are collected and transported to a central composting location.

The drop-off approach gives people the option of removing the material from their yards, but requiring them to move it, still providing an incentive for them to handle the material at home. A community can provide the composting service without having to worry about collection. Some small communities operating drop-off sites find that no additional personnel, equipment, or administrative costs are needed to run a successful site. If supervision is necessary, one person can usually oversee drop-off site operations.

The method of collection depends on many factors unique to the community.

The key to the success of a drop-off site is convenience. If drop-off sites are easy for most residents to get to (within a few miles of their homes), most will support the program. The proximity of the composting site always needs to be balanced against the chance of causing an odor nuisance in the community. Support for a drop-off program can often be increased by allowing local residents to take the finished compost for their own use. People can drop off a load of fresh yard trimmings and pick up a load of finished compost during one visit to the site.

Drop-off programs can present some problems for some residents. Often, elderly residents or those with physical problems are unable to carry the yard trimmings to the site without assistance. Others may also feel that transporting wet yard trimmings in plastic bags in a passenger vehicle is risky, because bags break. To avoid the costs and headaches involved in establishing a curbside collection program, it is worthwhile for a small or medium-sized community to work through these problems in order to make a drop-off site workable.

Curbside Collection

Some communities find that the drop-off approach does not satisfy their needs and decide to operate separate curbside collection programs. Collecting yard trimmings presents a variety of challenges. Because yard trimmings make up a significant portion of most municipal waste streams, handling it separately requires that decisions be made concerning pickup schedules and handling equipment. Revising pickup schedules to handle yard trimmings may require changing an existing route pattern and negotiating with unions or other labor representatives for increased staffing or overtime. If the community is served by a number of private haulers, the scheduling problems can become complex. In either case new equipment may be needed.

A major decision when establishing a curbside yard trimmings collection program is how residents should place the materials at the curb for pickup. The method of setting out yard trimmings will determine what equipment the community will need to efficiently pick it up. Different materials may need to be set out differently. A uniform policy should be made and enforced so residents know what is expected of them.

Different materials may need to be set out differently.

One method for setting out yard trimmings is to require that residents rake leaves, grass, or brush into piles to be collected at the curb. The material should either be placed between the sidewalk and the curb or in the street close to the curb. Different pieces of equipment are designed to collect the material in different locations. For example, a vacuum truck to collect leaves usually requires only that leaves be placed between the curb and the sidewalk. Other collection equipment, such as sweepers, may require that the material be in the street.

Yard trimmings piled in the street can cause other problems. Cars may run into and scatter the piles or children may play in them, creating a safety hazard. Precipitation can wash some of the piles into sewers, creating a flooding hazard or adding to the pollution load in the wastewater system.

Noncontainerized piling may work best for leaves and brush. Leaves tend to be light and dry and easily collected. Piled brush is fairly easily chipped and transported. Grass, on the other hand, is often dense and wet, and can create objectionable odors if left piled for more than a few hours.

For ease in handling yard trimmings, bags are often used. Frequently the bags used are made of materials that must be segregated from the yard trimmings. Removal steps can be costly, requiring either extra labor time or special processing equipment. Odors may also be a problem when emptying bags containing highly decomposable grass clippings.

Significant efforts have been made to eliminate the need to debag yard trimmings by developing biodegradable bags or by using paper bags. Each have shown promise, but reliability and cost constraints have limited their implementation. Ideal bags have the following features: they securely hold the yard trimmings until the bag has reached the composting site, are easily punctured or broken open so air can enter the materials, and they biodegrade in the compost as the materials are stabilized.

Rather than using bags, some communities use permanent bins for storing yard trimmings. For example, in a pilot program, the city of Omaha, Nebraska, has provided a group of residents with a 90-gallon, plastic, wheeled cart for storing yard trimmings. The carts are wheeled to the curb where they are lifted by special hoists and the contents dumped into a packer truck. Using these covered carts has reduced problems with odors and has generally been well accepted by Omaha's residents. Conventional garbage cans should not be used for yard trimmings because they are very heavy when full and can cause injury to workers when the cans are lifted into packer trucks.

Whether yard trimmings are collected loose, in bags, or in bins determines the type of collection equipment needed.

The decision to collect yard trimmings loose, in bags, or in bins will help determine the equipment that will be needed to efficiently collect the yard trimmings. Yard trimmings collection equipment can be divided into two categories: gathering devices and transport vehicles. Gathering devices move the yard trimmings from the street to the transport vehicle, which takes the trimmings to the compost site. Some equipment performs both functions. Still others are general purpose vehicles that handle yard trimmings using special attachments.

The types of gathering devices needed will depend on material types to be collected and how residents store the material at the curb. For leaves stored between the sidewalk and the curb, vacuum leaf collectors are popular. These collectors suck the leaves into a shredder, which blows the leaves into a collection vehicle. For some units the leaves are compacted as well. These units can be damaged if snow and ice are present in the leaf pile. Vacuum collectors may be used to collect grass, but materials with a higher moisture content are more difficult to handle with a vacuum truck.

A number of collection options are available for yard trimmings piles placed in the street near the curb. Front-end loaders are the most popular, since most communities already have one. Front-end loaders can pick up the yard trimmings and place them in a dump truck. For tight spaces or small piles, a dust or leaf pan can be attached to a jeep for similar collection. Street sweeper-type broom collectors are also becoming popular. These gathering vehicles sweep the yard trimmings into a processor where they are shredded and transported to a collection vehicle. The problem with this type of collection is that the curb must normally be free of vehicles for the broom system, which is normally quite long, to have free access to the curb.

Most communities use tree chippers to collect brush and wood. The chipper processes the material at the curb, and trucks transport the chips to a re-use site or disposal site. Some communities also run larger, high-volume chippers at the compost site, and transport unprocessed wood there to be chipped.

Combined Approaches

A combination of collection approaches may be best.

Many communities use a combined approach to manage yard trimmings. For example, Madison, Wisconsin, offers curbside pickup of leaves for limited periods in the spring and fall. Grass is not picked up, to encourage grasscycling and home management, but a number of drop-off sites have been established for those residents still desiring to remove grass or other greenery such as weeds from their property. Brush is picked up and chipped on a monthly schedule. Local private haulers offer pickup service as well. By looking at each type of yard trimming material separately, the most economic, efficient, and politically acceptable management approach can be chosen for each.

Preparing Yard Trimmings for Composting

If the drop-off or curbside collection program is managed to limit the inclusion of undesirable materials, a minimum of effort is needed to prepare yard trimmings for composting. Bags must be emptied or somehow punctured to allow air to pass through. When contamination is a problem, special steps must be taken to segregate and separately dispose of the undesirable materials, which can be very time-consuming and costly.

Pre-shredding of yard trimmings can speed up the rate of decomposition. However, besides increasing operational and equipment costs, pre-shredding will also increase the oxygen demand of the windrow, and require more pile turning or the use of forced aeration to avoid odor problems. For most yard trimmings composting programs, pre-shredding is probably not necessary.

Applicable Composting Technologies

There are a variety of methods for processing yard trimmings. In deciding which option or options to employ, the best approach is to try to adopt the simplest method available.

The most common method for yard trimmings composting is the windrow. With this method the material is placed in piles, which are turned periodically. By carefully choosing the pile sizes, the rate of decomposition can be optimized.

The windrow method is the most commonly used technology for composting yard trimmings.

Windrow composting works especially well with leaves, which break down more slowly than grass clippings. This makes management easier and the creation of nuisance conditions less of a problem. Where both leaves and grass are to be composted in the same pile, it is suggested that leaves be composted first and grass added later. Mixing the new grass with the already partially composted leaves reduces the potential for odor problems to develop. Grass decomposes quickly, sometimes even in the bag, and often will begin to emit objectionable odors associated with anaerobic decomposition very quickly unless the leaves are mixed with dryer, more stable materials as soon as possible. A 1:1 weight ratio (3:1 to 5:1 by volume) of leaves to grass clippings is desirable to provide an optimum carbon-to-nitrogen ratio, but a higher ratio of leaves to grass may be necessary to reduce odor potential. When the leaves and grass are collected also influences the ratio. If only leaves are collected, supplemental nutrients may be necessary.

For communities with large areas of sparsely inhabited land available to them, the "low-effort" composting approach may be the most economical.

For communities with large areas of sparsely inhabited land available to them, the "low-effort" composting approach may be the most economical. In the low-effort approach, windrows are formed and usually turned only once a year. Because infrequent or no turning creates anaerobic conditions in the windrow pile, the low-effort approach can be associated with strong odors when the pile is turned. If this approach is used, it is suggested that a large buffer zone be available. The low-effort approach usually takes about three years to make usable compost. Its advantage is that it takes only a few days per year of the community's personnel and equipment to operate the entire program.

Scientists at Rutgers University developed an effective method for composting leaves. In this approach, windrows are made large enough to conserve the heat of decomposition, but not so large as to overheat the piles, which adversely affects the microorganisms. The goal is to maintain an optimal temperature in the pile throughout the composting time period.

The Rutgers process is to receive leaves in a staging area rather than dumping them on the ground and immediately forming windrows. By using a staging area, the materials are better distributed in the windrow pile. Contamination of the feedstock can also be kept to a minimum. The leaves are formed into piles using a front-end loader, which moves the material from the staging area to the composting area. One acre can handle about 3,000 cubic yards of material.

As the front-end loader breaks the masses of leaves apart in preparation for creating the windrow, water is sprayed on the leaves. A rule of thumb is that 20 gallons of water are required per cubic yard of leaves collected. The need to add water can also be reduced by forming a flat or concave top on each windrow to catch rain or other precipitation, which then filters down through the material.

Once each windrow is formed, the piles should be monitored for temperature and moisture content. Any odor inside the windrow should be investigated to determine if an area of anaerobic decomposition is present in the pile (the largest volume of leaves is generated in the fall).

After approximately a month, the windrow piles should be about half their original size.

After approximately a month, the windrow piles should be about half their original size. Two piles should then be combined to form one pile of approximately the original size. Combining the piles will add needed oxygen to the process, as well as help conserve heat during the oncoming colder weather. The combined piles can be allowed to sit during the winter, but should be turned as soon as practical in the spring. Additional turnings throughout the spring and summer will enhance the rate of decomposition and ensure that pathogens and weed seeds present in the compost pile are destroyed. By late summer, the pile can be moved to the outer perimeter of the compost site and allowed to cure until the following spring.

Another approach initiated by Ramsey County, Minnesota can be used to compost both leaves and grass even during the cold winters in northern areas. First, windrows are built from leaves collected in the fall. The windrows are constructed with flat tops to retain water, but no additional water is added. The windrow is left in place during the winter to conserve the carbon. During the following spring and summer, new materials, including about 25 percent by volume grass clippings, are mixed into the existing pile. The windrow is turned by rolling it over into an adjacent area where it remains until the following spring, when it is rolled again and left for final curing. This composting process takes about 18 months to produce a finished compost.

Aerated static pile composting is also a possibility for yard trimmings. The advantage is that piles do not need to be moved, a premium where space is limited. The effectiveness of forced aeration may, however, decline if air channels develop in the pile. A similar approach is used in Maryland (Gouin, 1994). In the fall, the leaves are placed in windrows 6’-8’ high and 10’-15’ wide at the base. The windrows are left undisturbed all winter long. In the spring, as soon as the grass clippings are received, they are applied to the windrows at a 1:1 ratio by volume and mixed. This is accomplished by placing a windrow of grass clippings, of equal size, adjacent to the windrow of leaves and blending them together. This technique makes maximum use of all the available carbon from the leaves and minimizes odor problems from the composting of grass clippings. When there is an insufficient amount of leaves to dilute the grass clippings, ground brush is used at the same 1:1 ratio by volume. However, when using ground brush as a bulking agent, the piles can be recharged at 4 to 5 week intervals at the same 1:1 ratio (Gouin, 1994).

Facilities developed for yard trimmings composting must be carefully planned.

Facilities developed for yard trimmings composting must be carefully planned. The facility should be designed to efficiently receive yard trimmings from both large and small vehicles. Adequate space must be available for composting windrowing, curing, and storage. An example layout for yard trimmings composting is shown in Figure 7-7.

Processing for Markets

It may be necessary to shred and screen finished yard trimmings compost to satisfy market specifications. Sticks, twigs, other woody materials, or stones may make the compost unattractive to potential users. If the compost might be used in parks for a highway project, additional shredding and screening may not be necessary.

Product Characteristics of Yard Trimmings Compost

Yard trimmings compost has fewer plant nutrients than municipal wastewater treatment plant biosolids, livestock manure, or MSW-derived compost.

The compost's characteristics should be monitored.

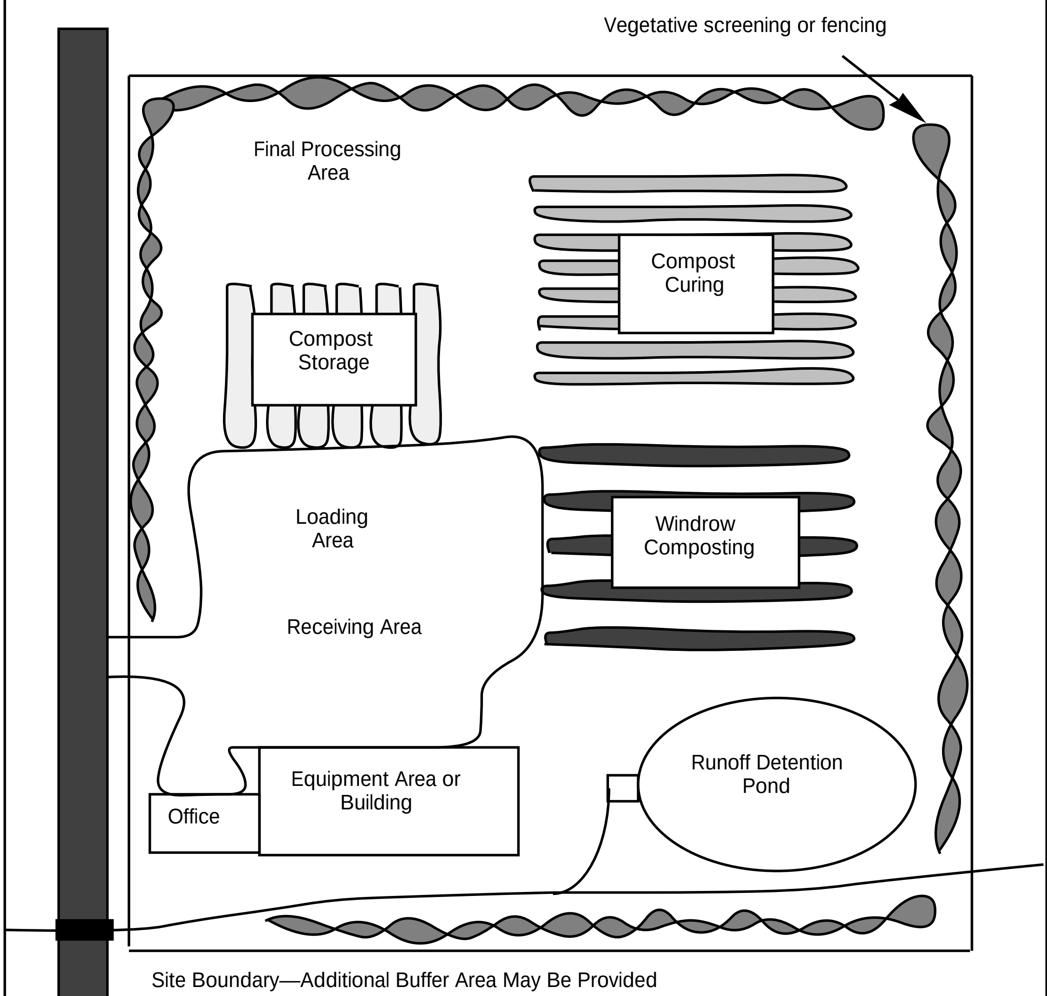
Samples of the finished yard trimmings compost should be analyzed for plant nutrients. On the other hand, heavy metal and pesticide contaminants are detected less often or are at lower concentrations in yard trimmings compost than in compost made from mixed MSW. Table 7-6 shows heavy metal concentrations found in two yard trimmings compost programs. The heavy metal contents varied, but remained below levels of soil concentrations toxic to plants, as well as below maximum levels established in Minnesota and New York for co-composted MSW and municipal sludge biosolids. Pesticide concentrations are shown in Table 7-7. Studies by Roderique and Roderique (1990) and Hegberg et al. (1991) indicate that under normal conditions heavy metals and pesticide residues detected in yard trimmings compost have generally been insignificant. Periodic testing should be done to determine if unanticipated concentrations of metals or pesticides are present in the finished compost.

Direct Land-Spreading of Yard Trimmings

Rather than compost yard trimmings, some communities and private haulers are directly land-spreading yard trimmings with agricultural or specially adapted distribution equipment. This approach bypasses the need to site and

Figure 7-7

Example of Yard Trimmings Composting Facility Site Layout



Source: University of Wisconsin–Madison Solid and Hazardous Waste Education Center, 199

Table 7-6

Heavy Metals in Yard Trimmings Compost

Heavy Metal	Croton Point, New York	Montgomery Co., Maryland[a]	Standard[b]
Cadmium (ppm)	ND[c]	<0.5	10
Nickel	10.1	NA[d]	200
Lead	31.7	102.7	250
Copper	19.1	35.5	1000
Chromium	10.5	33.6	1000
Zinc	81.6	153.3	2500
Cobalt	4.2	NA	NS[e]
Manganese	374.0	1,100.0	NS
Beryllium	15.0	NA	NS
Titanium(%)	0.09	NA	NS
Sodium	1.51	0.02	NS
Ferrous	2.67	0.96	NS
Aluminum	3.38	0.66	NS

(a) Average of 11 samples 1984-1985.

(b) For pesticides, standards are derived from USDA tolerance levels for pesticided in food (40 CFR Chapter 1, Part 180). For metals, standards are Class 1 Compost Criteria for mixed MSW compost, 6 NYCRR Part 60-5-3.

(c) ND = not detectable (d) NA = not available (e) NS = no standards

Source: J. O. Roderique and D. S. Roderique, 1990

operate composting facilities. The yard trimmings may be directly incorporated into the soil or left for later incorporation.

Some communities directly land-spread yard trimmings.

Direct land-spreading programs do have advantages, but they require careful management for several reasons to avoid soil fertility problems if the carbon:nitrogen ratio is too high. First, the available nitrogen in the soil may become tied up in the yard trimmings decomposition process and not be available to the crop. In addition, weed seeds, excessive runoff of organic materials, and odors may pose problems if the spreading site is poorly managed. Some state regulatory authorities may view spreading as a disposal practice and require special permits. Research is underway to better characterize the special challenges associated with higher-rate land-spreading of yard trimmings and the benefits of introducing additional organic matter into the soil profile.

Source-Separated Organics Composting

Source-separated organics composting is a relatively new approach being implemented, in part, to overcome some of the limitations of mixed MSW composting. The definition of source-separated organics is somewhat variable: food scraps are common to all definitions, yard trimmings may be included, and some programs handle small quantities of paper.

Waste Collection

In source-separated composting programs, organics are collected separately from other materials, such as recyclables and noncompostable material. The source-separated material is collected from residences and selected businesses, such as restaurants. Because these materials have a high moisture content, special liquid-tight containers are necessary for transporting them.

In European programs, specially made metal or plastic containers are provided to residents for their organic materials. A demonstration project in

Composting organic materials that have been kept separate from other materials reduces quality and production problems.

Connecticut collected the materials in conventional garbage bags onto which the residents placed brightly colored stickers indicating "Compostable Materials." The stickers helped the collection vehicle operators identify the organics and also helped remind the residents to carefully separate out their organic materials.

Given the innovative nature of this approach, special educational programs should accompany implementation. The primary advantage of source-separated organics composting is the ability to produce compost that is essentially free of contaminants. Accomplishing this depends on the conscientious efforts of generators and an effective collection program.

Preparing Materials for Composting

Depending on the material types collected, shredding may be necessary to reduce particle size for the particular compost technology being used. A bulking agent such as wood chips may also be necessary.

Table 7-7

Pesticide Analysis of Portland, Oregon, Yard Trimmings Compost

Pesticide Classification	Residue	Number of Samples[a]	Samples Above Detection Limit[b]	Mean[c] (mg/kg)	Range[c] (mg/kg)
Chlorophenoxy Herbicides	2,4-D	16	0	ND[d]	–
	2,4-DB	16	0	ND	–
	2,4,5-T	16	0	ND	–
	Silvex	16	0	ND	–
	MCPA	16	0	ND	–
	MCPP	16	0	ND	–
	Dichloroprop	14	0	ND	–
	Dicamba	16	0	ND	–
	Pentachlorphenal	14	9	0.229	0.001-0.53
Chlorinated Hydrocarbons	Chlordane	19	17	0.187	0.063-0.370
	DDE	14	3	0.011	0.005-0.019
	DDT	8	0	ND	–
	opDDT	14	2	0.005	0.004-0.006
	ppDDT	14	4	0.016	0.002-0.035
	Aldrin	16	1	0.007	0.007
	Endrin	16	0	ND	–
	Lindane	16	0	ND	–
Organophosphates	Malathion	14	0	ND	–
	Parathion	14	0	ND	–
	Diazinon	14	0	ND	–
	Dursban	15	1	0.039	0.039
Miscellaneous	Dieldrin	13	1	0.019	0.019
	Trifluralin	10	0[e]	–	–
	Dalapon	4	0	ND	–
	Dinoseb	5	1	0.129	0.129
	Casoron	8	0[e]	–	–
	PCBs	8	0	ND	–

(a) The number of samples is the combined total for 2 sources of compost sampled in June and October 1988; April, July and October 1989. The number of samples taken was not uniform (mostly 2 per period per source in 1988 and 1 per period per source in 1989).

(b) The minimum detection limit is 0.001 ppm for pesticides and 0.01 ppm for PCBs. (c) Dry basis

(d) Not detectable (ND) (e) Residue detected but not measurable

Source: Hegberg et al., 1991

Applicable Composting Technologies

New technologies are becoming available for source-separated organics composting.

Each of the technologies applicable to mixed MSW composting is also appropriate for source-separated organics. Special attention, however, must be given to nutrient balances. In-vessel systems with windrow or aerated static pile for curing are the most commonly used technologies. Methods for applying anaerobic digestion technology to this type of material are currently under study (Tchobanogous, 1993). Researchers have found that using an anaerobic digester followed by an aerobic digester composted almost all the biodegradable fraction of the organic matter in the feedstock.

Processing for Markets

In one Connecticut study, source-separated organics compost was screened twice: first after agitated bay composting and a second time after windrow curing (see Figure 7-8). Approximately 4 percent of the collected material was screened out by the first 2-inch screen and defined as non-compostable. The remaining cured compost was then passed over a 3/8-inch screen. Approximately 12 percent of this material was retained on the second screen and sent to a landfill. The discarded material included wood chips, brush, and some plastic film.

Product Characteristics of Source-Separated Organics Compost

Published studies to date of cured compost have found heavy metals and other chemicals to be in concentrations far below levels of concern. The chemical analysis is summarized in Table 7-8, which also shows heavy metal concentration in a mixed MSW compost for comparison.

Mixed MSW Composting Systems

Mixed MSW composting has been successful in a number of communities but has failed in several others.

Because a significant portion of residential and commercial solid waste is compostable, MSW composting programs can divert a substantial portion of a community's waste stream from land disposal. Composting, which requires sophisticated technology and specially designed facilities, has been successfully implemented in a number of communities but has failed, with rather dire financial repercussions, in several others.

Collection

The source of feedstock for a mixed MSW composter is usually conventionally collected residential and commercial solid waste. The type of collection container does not significantly impact the mixed MSW composting system, but bags must be opened before or during the process. A variety of materials that must be removed by screens later enter the composter.

The quality of the feedstock and consequently the compost product is enhanced when potential contaminants are segregated from the input stream. For example, a recycling program that diverts glass reduces the amount of glass in the compost. A program for source segregating household hazardous wastes has similar benefits. Careful supervision of materials collected from commercial facilities may forestall entry of potential contaminants from those sources.

Preparing Materials for Composting

As a first step a mechanical device may open the garbage bags. After the bags are opened some composting systems have conveyor lines, which move the materials past workers who manually remove recyclables. It is also inspected to detect undesirable materials. The waste is then shredded. This is usually

Waste preparation is a critical step.

accomplished by a low-speed shredder or by the grinding action that occurs in the first stage of an in-vessel composter.

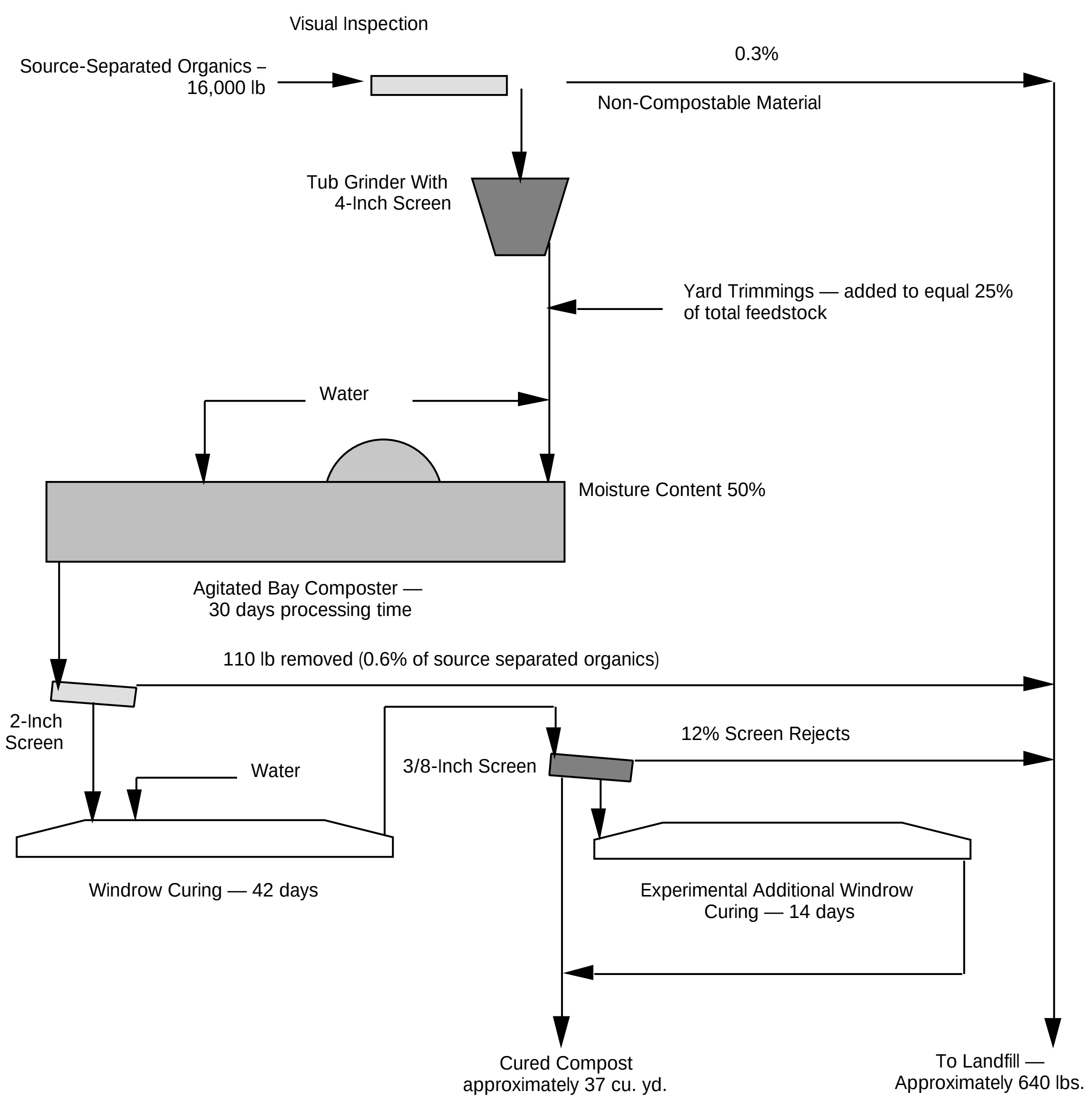
At some mixed MSW composting facilities the feedstock, after shredding, is more extensively processed through screens and trommels to segregate plastics, dirt, and other materials that are not suitable for composting. Magnetic and eddy current separation can be used to recover ferrous and aluminum. The recent trend appears to more aggressively process the waste stream before composting to improve its quality and to capture recyclables.

Applicable Composting Technologies

Typically, a two-stage process is used for composting mixed MSW. The first stage promotes rapid stabilization of the feedstock and the second stage achieves final curing. Aerated static pile, in-vessel, or anaerobic processes are

Figure 7-8

Example of Source-Separated Organics Composter Material Flow and Mass Balance



Source: Wet Bag Compost Demonstration Project, Greenwich and Fairfield, Connecticut, 1993

Compare the various technologies before selecting a mixed MSW composting system.

usually the first stage, and turned windrow or aerated static pile is the second-stage curing technology. The combination of technologies depends on the proprietary process selected, space considerations, and operating preferences.

No single technology has an outright advantage over another but recent experience has shown that a system must be carefully developed and operated to achieve success. Several large mixed MSW composting facilities have closed as result of operational problems, principally odors. Often, inadequate financial support is a contributing factor, as it precludes solving odor and other problems.

Aerated static piles are best suited to sites which have suitable land available for the piles and a buffer area. The shredded MSW is placed in piles that are 5 to 8 feet high and 10 to 16 feet wide. A critical design factor is to achieve uniform distribution of air through the length of the pile. A 6 inch cover of cured compost is initially placed over the pile to control odors. In the negative pressure mode, air is drawn into the pile by blowers that then discharge into a biofilter of cured compost. The cured compost acts as an odor filter. A positive pressure aeration system involves blowing air into the compost pile. This approach is simpler to set up but is more susceptible to odor problems. The pile's internal temperature is monitored to assess process performance. Compost is ready for final curing in 6 to 12 weeks.

Table 7-8

Examples of Inorganic Constituents in Compost

Inorganic Constituents (ppm)	Wet-Bag Compost[a]	Source Separated Organics[b]	Mixed MSW[c]
Regulated Elements			
Arsenic	2.1		
Cadmium	1.2	0.8	7.0
Chromium	20.0	29.0	180.0
Copper	173.0	43.0	600.0
Lead	92.0	76.0	800.0
Mercury	1.7	0.2	
Molybdenum	<22.0		
Nickel	17.0	7.0	110.0
Selenium	<1.0		
Zinc	395.0	235.0	1700.0
Other Elements			
Aluminum	5700.0		
Antimony	<140.0		
Barium	172.0		
Beryllium	0.26		
Boron	<29.0		
Calcium	19000.0		
Chloride	4400.0		
Cyanide	<1.0		
Iron	9600.0		
Magnesium	3600.0		
Manganese	440.0		
Silver	<6.0		
Sodium	1800.0		
Titanium	230.0		

Sources: (a) D. Stilwell, 1993 (b) U. Krogmann, 1988 (c) J. Oosthnoek and J. P. N. Smit, 1987

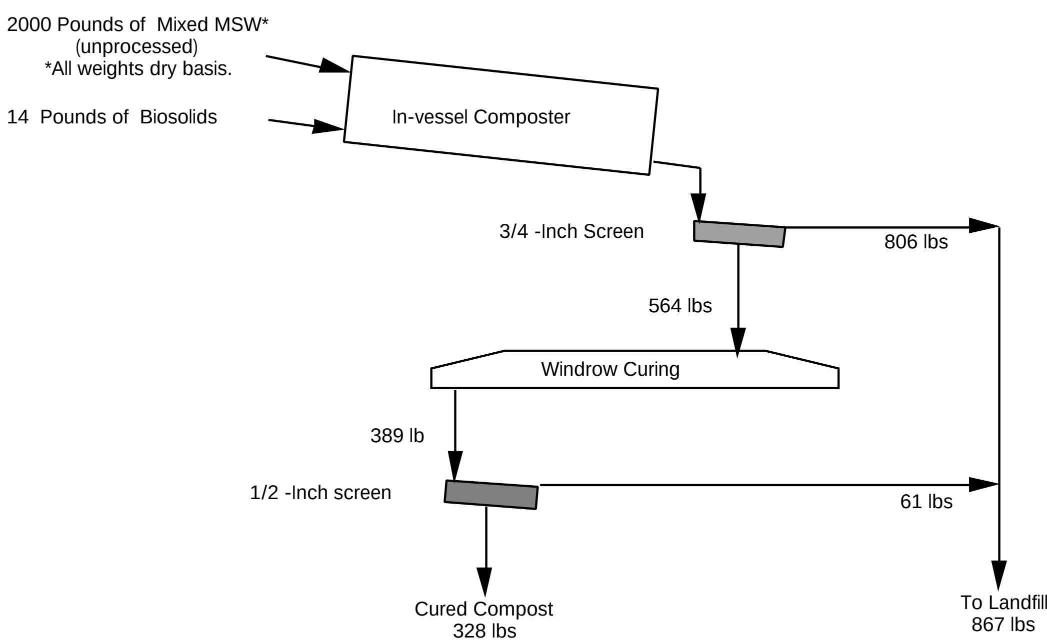
Several alternative configurations are available for the aerated static pile. The pile may be periodically turned to ensure more uniform compost production. Feedstock placed in piles may be located between retaining walls. Air is distributed through the floor and the stabilizing compost is periodically agitated.

Currently the most common type of in-vessel systems are an inclined rotating drum into which MSW is loaded in time periods ranging from every few minutes to hours. The MSW may not have been previously shredded depending on the particular proprietary process being used. The waste moves gradually down the inclined drum towards a discharge hatch. The hatch, when open, allows compost to be discharged. The detention time in the drum ranges from 3 to 15 days. After the mixed MSW compost exits the drum it may be screened to remove large objects that did not biologically decompose or were not mechanically broken down in the drum. The material passing through the screens is ready for further composting or final curing if the drum has a long detention time. The waste retained by the screens is usually landfilled. A material flow and mass balance for an in-vessel composter is shown in Figure 7-9. Other configurations of in-vessel systems are produced by various manufacturers. Each design should be carefully evaluated when selecting equipment.

Odor problems occurring with aerated static pile and in-vessel mixed MSW composting have been the principle operating problem. Operating controls must be carefully managed to insure that aerobic conditions are maintained throughout the entire system. Various types of odor control equipment have been installed to filter or mask odors. An experienced technical specialist should be consulted for incorporating odor control methods in the process.

Figure 7-9

Example of Mixed MSW Composter Material Flow and Mass Balance



Feedstock	
Mixed MSW	2000 lbs
Biosolids	14
Total	2014

Output		
Cured Compost	328 lbs	16 %
Landfilled Residue	867	43
Weight Lost to Atmosphere	819	41
Total	2014	100

Source: Razvi and Gildersleeve, 1992

Anaerobic processes have been studied extensively for mixed MSW but there is only limited full-scale operating experience. Higher capital costs and operating problems during testing appear to be the principle factors that have slowed using anaerobic processes for mixed MSW. These systems are totally enclosed and therefore less subject to odor problems than aerobic systems. Methane is produced as a by-product so that the net energy balance is positive.

Once the feedstock has completed first-stage composting it is ready to be cured. Curing is a continuation of the composting biological process but at a slower rate and is less equipment- and cost-intensive. Windrows that are periodically turned, aerated static piles, or a combination of the two, are the normal curing method. Curing usually takes 3 to 9 months.

Processing for Markets

When curing is completed, the mixed MSW compost is ready for final processing. This usually involves a one- or two-stage final screening to remove inert materials and possibly an intermediate grinding step to reduce particle size. The final processing depends greatly on the needs and specifications of the compost users.

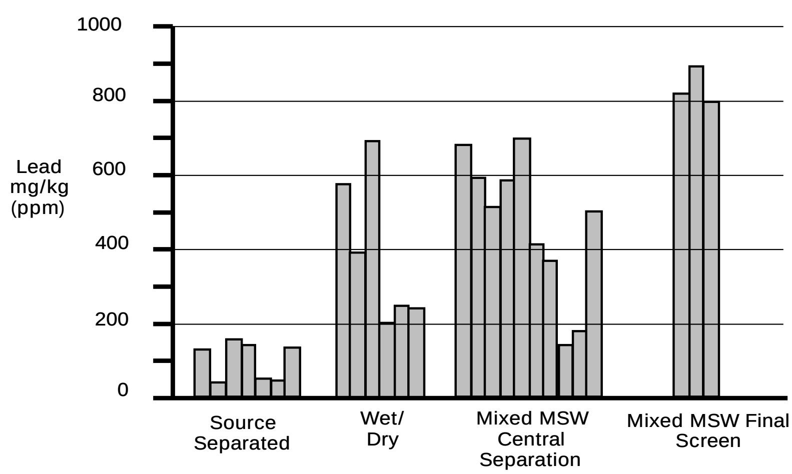
Product Characteristics of Mixed MSW Compost

The composition of mixed MSW compost is influenced by feedstock characteristics, collection methods, processing steps, and composter operating procedures.

In order to market mixed MSW compost to many end users, concerns about potential threats to plants, livestock, wildlife, and humans must be addressed. One of the primary concerns is the presence of heavy metal compounds (particularly lead) and toxic organic compounds in the MSW compost product. To date, where problems have occurred with mixed MSW compost, they have resulted from immature composts, not metals and toxic organics (Chaney and Ryan, 1992; Walker and O'Donnell, 1991). Manganese deficiency in soil and boron phytotoxity as a result of mixed MSW compost application can be potential problems. Measures, including further separation by generators or at the facility, can be taken to prevent problems and produce a high quality compost. Figure 7-10 shows the variations in lead concentrations which have been reported in different types of compost. The influence of source separation on lead content is readily apparent. The composition of mixed MSW compost is influenced by feedstock characteristics, collection method, processing steps, and composter operating procedures.

Figure 7-10

Lead Concentrations in Various Types of Compost



Source: T. Richard and P. Woodbury, 1993

Testing compost for chemical constituents must be carefully planned and executed. Wide variations in metal concentrations within the same compost pile have been reported. Woodbury and Breslin (1993) found only small variations in copper concentration at one compost facility. However, ten samples collected at a second facility had copper concentrations ranging from 300 to 1180 parts per million. Sampling and testing programs for mixed MSW compost must be carefully planned and executed. The program must recognize the inherent variations that will influence test results. See Cornell Waste Management Institute MSW Composting Fact Sheet #7, "Key Aspects of Compost Quality Assurance," for more detailed information regarding sampling and testing protocols.

OPERATIONAL CONSIDERATIONS AND CONCERNS

Housekeeping

The appearance of the compost facility should be appealing from the outside. Any wind-blown paper near the site should be picked up routinely. Streets, parking areas, and weighing areas should be free of dust and mud. Use as much compost as needed to provide landscaping for the site.

Indoors, the floors and equipment should be cleaned periodically and maintained in a dust-free manner. Areas where compost or other recovered materials are likely to spill should be cleaned immediately when spills occur. The cause of the spill should be taken care of immediately.

Leachate

Poor water management at a compost site can lead to water pollution and odor problems.

Leachate is the free liquid that has been in contact with compost materials and released during the composting process. Even well-managed composting operations will generate small quantities of leachate. Leachate pools are a result of poor housekeeping and may act as a breeding place for flies, mosquitoes, and odors. Leachate can also contaminate ground- and surface-water with excess nitrogen and sometimes other contaminants. For these reasons, leachate must be contained and treated. It is advisable for the composting facility design to include a paved floor and outdoor paved area equipped with drains leading to a leachate collection tank. Leachate may be transported and treated at a wastewater treatment plant or mixed as a liquid source with the incoming material. Leachate may contain pathogens, and therefore must not be returned to material that has been through the pathogen destruction stage.

Piles left outdoors (without a roof) will be exposed to rain, which will generate leachate. Attempts must be made to minimize leachate production by diverting any surface-water runoff from the up-slope side of the piles. Another method is to shape the peak of the pile concave, so the rain water will soak into the pile rather than shed off the pile.

Odor and Dust Control

Offensive odors may be generated during the active stage of composting. The intensity of odors increases if composting conditions are not controlled within narrow tolerance limits from the ideal. Process air should be routed through filters, deodorizers, or scrubbers before it is exhausted to the atmosphere. If there are odors, the specific source and type of odor should be identified; this may be difficult to do with mixed MSW. Masking agents are specific to certain types of odors and have worked with a limited degree of success. Scrubbers are efficient in removing a significant portion of odors, but they do not remove all odors.

The use of "biofilters" in composting to treat odorous compounds and potential air pollutants is expanding. Biofiltration involves passing odorous gases through a filtration medium such as finished compost, soil, or sand. As the gases pass through the medium, two removal mechanisms occur simultaneously: adsorption / absorption and biooxidation (Naylor et al. 1988, Helmer, 1974). The biofilter medium acts as a nutrient supply for microorganisms that biooxidize the biodegradable constituents of odorous gases.

The degree of odor control needed depends in part on the facility's proximity to residences, businesses, schools, etc. For example, some facilities located in remote areas have operated without any odor control devices.

Odor and dust control require careful attention to a number of operational factors.

Odors can also be generated if unprocessed or processed feedstock containing putrescible materials has been stored for an extended period. Every attempt should be made to process the feedstock as soon as possible after it is received, while it is in optimal condition for composting.

Air from the tipping floor and material processing and separation areas and exhaust air from the actively composting materials should be captured and treated or diluted with large amounts of fresh air before it is dispersed into the atmosphere. Exhaust air from composting materials is generally warm and almost always contains large amounts of moisture. This air may be corrosive and could affect equipment and buildings. During winter months, if ambient temperatures are cool, exhaust gases can fog up the work area, affecting visibility; the resulting condensate can affect the electrical system. This is common in northern climates where piles are placed indoors and turned.

The ventilation system must be able to remove the humidity and dust from the air. Adequate fresh air must also be brought into the buildings where employees are working. In such work areas, the air quality should meet minimum federal standards for indoor air quality.

In addition, operators should be aware of *Aspergillus fumigatus*, a fungus naturally present in decaying organic matter. It will colonize on feedstocks at composting facilities. Spores from the fungus can cause health problems for some workers, particularly if conditions are dry and dusty. Workers susceptible to respiratory problems or with impaired immune systems are not good candidates for working in composting facilities.

Siting a facility at a remote location so as to provide a large buffer zone between the composting facility and any residents should help alleviate odor-related complaints.

Personnel

Composting facility personnel are responsible for operating the plant efficiently and safely. Personnel must be trained so they understand all aspects of the composting process. Employees should appreciate the public relations impact the facility may have, and they should be taught to portray a positive image at all times. Employees should be trained in safety, maintenance, monitoring, and record keeping at the facility. Employees should also understand the environmental impacts of the finished compost and liquid / gas release to the atmosphere.

Monitoring

Routine testing and monitoring is an essential part of any composting operation. Monitoring the composting process provides information necessary to maintain a high-quality operation. At a minimum the following should be monitored:

- compost mass temperatures
- oxygen concentrations in the compost mass
- moisture content
- particle size

- maturity of the compost
- pH
- soluble salts
- ammonia
- organic and volatile materials content.

Record Keeping

Record keeping is an essential part of any operation. Maintaining detailed records provides a historical record of the operation and the improvements made over the years. Good records also provide a basis for building political support. Periodically evaluating records helps identify where improvements are needed and provides information necessary for making the operation more efficient. Records are the basis for quality control, safety, and minimizing down time in any operation. Records should be kept on employee safety training, facility and employee safety procedures, and health monitoring at the facility.

Good record keeping can result in better decision making in the long run.

The importance of keeping good records should be understood by all employees. They should be trained in accurate record-keeping methods and should know that they will be held accountable for keeping accurate records. At a minimum the following records should be maintained:

- incoming materials (solid and liquid) weights and types
- recyclables recovered and shipped
- noncompostable fraction recovered and shipped to landfill
- amount of compost made/shipped in different forms (buyer/client lists)
- amount of residence time required to make the compost (time, material received, placed into windrows, turning frequency, etc.)
- inventory of supplies/equipment
- maintenance record of equipment
- routine monitoring data
- marketing and distribution
- permits and approvals
- monitoring and testing
- accidents
- personnel (training, evaluation, health)
- expenses and revenues
- major problems and how they were corrected
- complaints and how they were resolved
- public information and education activities
- health and safety training, procedures, and precautions.

Public Information

Open, positive, communication with community leaders and neighbors should be ongoing. Good communication is critical if there is a problem at the site. Brochures describing the facility and its operations should be printed and distributed throughout the community. Neighbors, civic organizations, and school groups should be invited to take educational tours of the facility. Well-trained employees who understand the facility and its impact on the community can also contribute to public relations.

Objective, factual information should be continuously distributed to the public.

To ensure good relations, the public should be periodically informed of the types of materials accepted, those that are not accepted, and the collection schedules. If the finished compost is to be made available for public distribution, a distribution policy (costs, potential uses, when and where to pickup, risks, etc.) should be developed and publicized in the community. A well-planned and executed public information program can build significant support for the facility. The community needs to be periodically reminded that composting is an effective management tool and that having such a facility is evidence that the community is progressive and environmentally conscious.

Complaint Response Procedure

A complaint and response procedure must be developed. For all complaints, the names, time, date, nature of complaint, and the response made by facility personnel should be recorded. Any action taken must be communicated to the person complaining and recorded.

Complaints should be promptly responded to.

The most common complaint is about odors. These complaints normally come from those most likely to be exposed—neighbors. Individuals' sensitivity and tolerances to odor varies and some neighbors may call more frequently than others. Take all complaints seriously and attempt to resolve the situation as soon as possible after the complaint.

FACILITY SITING

One of the most important issues in selecting a composting site is its potential to generate odors. Odors from a facility can be strong enough to cause public opposition. When odors become a problem, public pressure may be intense enough to force the facility to close.

Every attempt should be made to minimize the impact of odors to local residents. It is best to avoid sites that may be located close to populated areas of a community. A thorough evaluation of the microclimatology (local weather conditions such as prevailing wind direction) of a potential site is critical to avoid future complaints from neighbors. Odor control devices should be installed, but their installation may add significantly to costs, and alone may not guarantee complete odor removal.

Other nearby odor sources should be evaluated. Locating a composting facility in a comparable land use zone such as at a landfill or wastewater treatment plant site may be one option. The neighboring land use may somewhat influence the sizing of the odor control equipment installed at the composting facility. In addition, zoning requirements may allow the composting facility and landfill wastewater treatment plant to be sited together.

Many factors must be considered when selecting a composting site.

Construction of a composting facility at an existing landfill has its benefits. One of the major advantages is the savings in transportation costs for the noncompostable and nonrecyclable wastes. A second advantage is that the difficulty of acquiring a site is significantly reduced. In addition, the neighbors are accustomed to the traffic patterns of the waste hauling trucks.

If composting biosolids is a project objective, locating the facility at the wastewater treatment plant should be considered. If a composting facility should be sited independent from an existing wastewater treatment facility, an isolated site where odors may not cause problems should be seriously considered. Other considerations for siting a composting facility include the following:

- potential for release of contaminants to surface and ground waters
- potential for airborne dissemination of contaminants (dust, litter, spores, etc.)
- distance from where feedstock materials were generated to the compost facility

- distance to compost markets
- distance to landfill
- traffic patterns / roads to and from the facility
- buffer zones for visual / noise screening and odor dilution
- availability of appropriate utilities
- appropriate soil types and geotechnical conditions
- drainage patterns
- flood hazard
- past ownership and usage
- zoning limitations
- room for future expansion of the facility
- anticipated growth and development near the facility.

The size of the site needed will depend on the composting system selected.

The size of the site needed will depend on the composting system selected. For example, an in-vessel system requires less land space than a static pile or windrow system. Site size will also depend on the amount of storage that will be provided. At a minimum four months of storage space must be available at the site. Sizing should be based on projections of anticipated feedstocks and increase in generation of existing feedstocks. A large buffer zone should be planned around the facility to minimize odor-related complaints from neighbors.

Public participation is crucial in the siting and planning process. Encouraging the public to participate during the planning process is both time-consuming and expensive. In the long run public participation will pay off because it will provide greater political support for the project, help promote interest in the compost product, and help develop local markets, which in turn will reduce transportation costs. In addition, as participants in the program, local residents may tolerate and even overlook some minor problems in the future.

GOVERNMENT APPROVALS, PERMITS, AND ORDINANCES

Make a list of necessary permits and approvals before starting a compost facility development project.

Composting facilities may need approvals / permits from the state before they can begin operating. The requirements for permitting composting facilities may vary among states. Submittal requirements as a prerequisite for permitting may include detailed facility design, operating plans, a description of incoming materials, the amount and types of residue to be generated in the plant, monitoring plans, potential environmental releases, landfills to be used, potential markets for the compost, etc.

State agencies may also issue public notices offering interested citizens an opportunity to have input and comment relative to the request for permit. In addition to a state-level permit, there may be additional local-level permits required, such as building permits, zoning variances, or special land use.

Sometimes new ordinances are required for compost facility siting, operation, and management. These ordinances may focus on centralized community yard trimmings facilities, mixed MSW composting facilities. Flow control agreements may be required for the facility to operate with a minimum amount of waste (see Chapter 3 for a discussion of flow control). Supply agreements should broadly define the types of feedstocks that will be accepted and the service area from which they will be accepted.

PROJECT FINANCING

Obtaining the necessary financing is an integral part of planning a composting project. The most common methods of financing a project are through bond

A variety of financing methods may be available.

sales or bank loans. A financing professional should be consulted for advice and assistance to coordinate necessary transactions and obtain favorable interest rates and payment terms. Some communities have budgeted for and used tax revenues to construct a composting facility. In such cases project construction could be spread over two or more years. Approval of any financing may be contingent on review of a detailed budget for the construction and operation of the facility, all necessary regulatory approvals, and details of marketing arrangements for the compost.

REFERENCES

Apotheker, Steve. 1993. *Resource Recycling.* April 1993.

Buhr, A.R., McClure, T., Slivka, and R. Albrecht. 1993. “Compost Supply and Demand,” *BioCycle* (January).

Chaney, R. L. and J. Ryan. 1992. “Heavy Metals and Toxic Organic Pollutants in MSW Composts,” cited in Hoitnik et al., eds. Proceedings of the International Composting Research Symposium (in press).

Chen, Yona and Yoseph Inbar. 1993. “Chemical and Spectorscopical Analyses of Organic Matter Transformations During Composting in Relation to Compost Maturity,” *Science and Engineering of Composting*, Renaissance Publications, Worthington, Ohio.

Composting Council. 1992. *Potential U.S. Applications for Compost.* The Composting Council, 114 S. Pitt St., Alexandria, VA 22314. Phone: 800 / 457-4474.

Dickson, et al. 1991. *Composting to Reduce the Waste Stream* (NRAES-43). This publication is available from NRAES, Cooperative Extension, 152 Riley-Robb Hall, Ithaca, NY 14853-5701, (607) 255-7654.

Dane County, University of Wisconsin–Extension, Wisconsin Department of Natural Resources, and Dane County Public Works. 1992. *Home Composting Handbook.*

Gould, Mark, et al. 1992. “Source Separation and Composting of Organic Municipal Solid Waste,” *Resource Recycling,* July 1992.

Hammer, S. 1992. “Garbage In / Garbage Out: A Hard Look at Mixed MSW Composting," *Resource Recycling* (February).

Hegberg, B.A., W.H. Hallenbeck, G.R. Brenniman, and R.A. Wadden. 1991. "Setting Standards for Yard Waste Compost," *Biocycle.* February.

Helmer, R. 1974. "Desodorierung von geruchsbeladener abuft in bodenfiltern. *Gesundheits-Ingenieur* 95(1):21. As cited in Williams and Miller. 1992. "Odor Control Using Biofilters, Part I," *BioCycle* (October).

Hoitink H.A.J., M.J. Boehm and Y. Hadar. “Mechanisms of Suppression of Soilborne Plant Pathogens in Compost-Amended Substrates,” *Science and Engineering of Composting*, Renaissance Publications, Worthington, Ohio.

Inbar Y., Y. Chen, Y. Hadar, and H.A.J. Hoitink. 1990. “New Approaches to Compost Maturity,” *BioCycle* (December).

Jewell, W. J. 1979. “Future Trends in Digester Design,” in D. A. Stafford et al. ed., *Proceedings of the First International Symposium on Anaerobic Digestion.* Cardiff, Wales. London: Applied Science Publishers, Ltd.

Jewell, W. J., R. J. Cummings, and B. K. Richards. 1993. "Methane Fermentation of Energy Crops: Maximum Conversion Kinetics and *In Situ* Biogas Purification." *Biomass and Bioenergy* 5(4).

Kayhanian, M. and G. Tchobanoglous. 1992. "Pilot Investigations of an Innovative Two-Stage Anaerobic Digestion and Aerobic Composting Process for the Recovery of Energy and Compost from the Organic Fraction of MSW," paper presented at the International Symposium on Anaerobic Digestion of Solid Waste, Venice, Italy, April 15-17.

Knoop, W. and B. Whitney. 1993. *Don't Bag It Lawn Care Guide.* Texas Agricultural Extension Service, 17360 Colt Road, Dallas, TX 75252.

Krogmann, Uta. 1988. "Separate Collection and Composting of Putrescible Municipal Solid Waste in W. Germany," ISWA Proceedings, Copenhagen.

LaGasse, R. C. 1992. "Marketing Organic Soil Products," *BioCycle* (March).

Logsdon, Gene. 1989. "New Sense of Quality Comes to Compost," *BioCycle* (December).

Naylor, L.M., G.A. Kuter, and P.J. Gormsen. 1988. "Biofilters for Odor Control: the Scientific Basis," *Compost Facts*. Hampton, NH:International Process Systems, Inc.

Oosthnoek, J. and J.P.N. Smit. 1987. "Future of Composting in the Netherlands," *Biocycle* (July).

Pfeffer, J. T. and J. C. Liebman. 1976. "Energy from Refuse by Bioconversion, Fermentation and Residue Disposal Processes," *Resource Recovery and Conservation*.

Razvi, Aga S. and Melissa Gildersleeve. 1992. *Physical/Chemical Mass Balance During Composting at the Portage, Wisconsin Facility*. Solid Waste Management Center, College of Natural Resources, University of Wisconsin-Stevens Point.

Richard, T.L. 1992. "The Key to Successful MSW Compost Marketing," *BioCycle* (April).

Richard, T. L. and P. Woodbury. 1993. *Strategies for Separating Contaminants from Municipal Solid Waste.* MSW Composting Fact Sheet No. 3. Cornell Waste Management Institute.

Richards, B.K., R.J. Cummings, W.J. Jewell, F.G. Herndon, and W.J. Jewell. 1991. "High Solids Anaerobic Methane Fermentation of Sorghum and Cellulose." *Biomass and Bioenergy*. 1(1): 47-53.

Richards, B.K., R.J. Cummings, W.J. Jewell, and T.E. White. 1991. "Methods for Kinetic Analysis of Methane Fermentation in High Solids Biomass Digesters." *Biomass and Bioenergy*. 1(2): 65-73.

Richards, B.K., R.J. Cummings, and W.J. Jewell. 1991. "High Rate Low Solid Anaerobic Methane Fermentation of Sorghum, corn and Cellulose." *Biomass and Bioenergy*. 1(5): 249-260.

Roulac, J. and M. Pedersen. 1993. "Home Composting Heats Up," *Resource Recycling* (April).

Rynk R. et al. 1992. *On Farm Composting Handbook.* Northeast Regional Agricultural Engineering Service. Available from NRAES, Cooperative Extension, 152 Riley-Robb Hall, Ithaca, NY 14853-5701, (607) 255-7654.

Slivka, D.C.; T.A. McClure; A.R. Buhr; and R. Albrecht. 1992. "Compost: National Supply and Demand Potential," *Biomass and Bioenergy*.

Stilwell, D. 1993. *Compost Science and Utilization.* Connecticut Agricultural Experiment Station (in press).

Walker, J. M. and M. J. O'Donnell. 1991. "Comparative Assessment of MSW Compost Characteristics," *BioCycle (August).*

Woodbury P. and V. Breslin. 1993. *Key Aspects of Compost Quality Assurance*. MSW Composting Fact Sheet No. 7. Cornell Waste Management Institute.

Wujcik, W.J. and W.J. Jewell. 1980. "Dry Anaerobic Fermentation." *Biotechnology and Bioengineering Symposium.* No. 10, pp. 43-65.

8 ❖ COMBUSTION

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A decision many communities face is determining whether a waste-to-energy (WTE) system might be a feasible component of their integrated solid waste management program. The amount of waste combusted or expected to be handled by combustion systems through the year 2000 is shown in Table 8-1.

For some communities, developing a WTE project can be a lengthy and expensive process that requires making decisions which have long-term consequences. It is necessary, therefore, to follow a step-by-step process for evaluating the feasibility of constructing and operating a WTE facility. It is also crucial to acquire adequate information to understand the legal, technical, financial, and regulatory issues that must be addressed when considering a WTE system. This chapter describes the issues that communities should consider when evaluating the feasibility and appropriateness of including a WTE facility as part of their integrated solid waste management plan.

Table 8-1

Generation, Recovery, Combustion, and Disposal of Municipal Solid Waste, 1993 and 2000 (At a 30 Percent Recovery Scenario in 2000; In thousands of tons and percent of total generation)

	Thousands of tons		% of generation	
	1993	2000	1993	2000
Generation	206,940	217,750	100.0%	100.0%
Recovery for Recycling	38,490	54,245	18.6%	24.9%
Recovery for Composting*	6,500	11,175	3.1%	5.1%
Total Materials Recovery	44,990	65,420	21.7%	30.0%
Discards after Recovery	161,950	152,330	78.3%	70.0%
Combustion**	32,920	34,000	15.9%	15.6%
Landfill, Other Disposal	129,030	118,330	62.4%	54.3%

* Composting of yard trimmings and food wastes. Does not include backyard composting.

** Combustion of MSW in mass-burn or refuse-derived form, incineration without energy recovery, and combustion with energy recovery of source-separated materials in MSW.

Note: Percentages may not add to 100 due to rounding

Sources: USEPA. *Characterization of Municipal Solid Waste in the United States: 1994 Update*

From: Decision Maker's Guide to Solid Waste Management, Volume II, (EPA 530-R-95-023), 1995. Project Co-Directors: Philip R. O'Leary and Patrick W. Walsh, Solid and Hazardous Waste Education Center, University of Wisconsin-Madison/Extension. This document was supported in part by the Office of Solid Waste (5306), Municipal and Industrial Solid Waste Division, U.S. Environmental Protection Agency under grant number CX-817119-01. The material in this document has been subject to Agency technical and policy review and approved for publication as an EPA report. Mention of trade names, products, or services does not convey, and should not be interpreted as conveying, official EPA approval, endorsement, or recommendation.

8 ❖ HIGHLIGHTS

Evaluate the project's usefulness and feasibility.

(p. 8-7)

Developing a WTE (Waste-to-Energy) project is often a lengthy and expensive process, lasting several years. It is crucial to carefully evaluate whether WTE is appropriate for your community.

Figure 8-1 diagrams a systematic evaluation and development procedure for communities to follow.

Establishing a project development team should be the first step.

(p. 8-8)

The technological, legal and other complexities involved in developing a WTE facility will require a range of professional expertise over an extended time. Creating a project development team in the initial stage is crucial. The team should include at least the following:

- project engineer
- financial advisor
- attorney
- operator
- regulatory officials.

Is WTE right for your community?

(p. 8-9)

To determine if an energy recovery facility is feasible and desirable for your community, the following questions must be answered. If the answer is "no" to even one, WTE will probably not be appropriate.

- Is the waste stream sufficient after waste reduction, composting, recycling, etc. are considered? Will this be true for the foreseeable future?
- Is there a buyer for the energy to be produced?
- Is there strong political support for a WTE facility?

What area will the facility serve?

(p. 8-12)

The governmental body planning the WTE system should determine the region it will serve. The amount of waste generated in an area will be a determining factor. The area may include one or more municipalities, a single county, or several counties. A study can determine which of several possibilities is most appropriate. Some examples include the following:

- building one large facility serving the entire region
- building several facilities located strategically to serve the entire region
- constructing one or more units to serve only the region's more populated areas.

WTE facilities must produce significant income.

(p. 8-12)

WTE facilities have high capital and operating costs. This means finding buyers willing and able to sign long-term contracts for purchasing energy or power.

Finding buyers requires marketing initiative.

(p. 8-16)

To successfully market WTE energy requires knowledge of buyers' needs and the ability to convince potential buyers that the facility will be able to meet their needs. Marketers must consider these three factors crucial to all buyers: price, service and schedule, and reliability of energy supply.

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Several WTE technology options are available.
(p. 8-17 — 8-27)

- *Modular incinerators (15-100 tons-per-day):* These are usually factory-assembled units consisting of a refractory-lined furnace and waste heat boiler, both of which can be preassembled and shipped to the construction site. Capacity is increased by adding units.
- *Mass-burning systems (200-750 tons-per-day per unit):* Mass-burn systems usually consist of a reciprocating grate combustion system, refractory-lining on the bottom four feet, and water-walled steam generator. These systems produce a higher quality of steam (pressure and temperature) than modular systems.
- *Refuse-derived fuel (RDF) systems:* Two types of RDF systems are currently used. Shred-and-burn systems require minimal processing and removal of noncombustibles; and simplified process systems, which remove a significant portion of the noncombustibles.

Controlling emissions is a crucial concern.
(p. 8-28 — 8-31)

WTE technology has recently seen tremendous improvements in emission controls. This chapter discusses controls for the following emissions:

- volatile organics
- NO_x
- acid gas
- particulates
- secondary volatile organics and mercury.

CEM equipment is required for all new facilities.
(p. 8-31)

CEM (Continuous Emission Monitoring) systems monitor stack emissions of NO_x, carbon monoxide, oxygen, particulate via opacity meters, and acid gases via monitoring sulfur dioxide. Gas temperatures are also monitored to control the scrubber process and to ensure baghouse safety.

Facilities must acquire the appropriate permits and licenses.
(p. 8-31 — 8-35)

Permitting and licensing are complex technical processes. Ensuring that the facility is successfully permitted requires enlisting an experienced and qualified consulting firm to prepare the necessary studies and documents.

Facilities must meet federal and state regulations.
(p. 8-31 — 8-34)

The project team must become familiar with both federal and state regulations. Keep in mind that state regulations may be more stringent than federal. The following federal requirements are discussed in this chapter.

- New Source Performance Standards (NSPS)
- National Ambient Air Quality Standards (NAAQS)
- Prevention of Significant Air Quality Deterioration (PSD) review process for attainment areas
- New Source Review (NSR) for non-attainment areas
- Operating Permit Review and periodic renewal.

8 ❖ HIGHLIGHTS (continued)

"SIPs" are required in every state.
(p. 8-34)

SIPs (State Implementation Plans) are a set of state air pollution emission regulations and controls designed to achieve compliance with the NAAQS. SIPs must contain requirements addressing both attainment and nonattainment areas.

Disposal of residual materials is another crucial concern.
(p. 8-35 — 8-36)

WTE facilities produce a variety of residues: bottom ash constitutes the largest quantity, fly ash is a lighter emission. Constituents in ash and scrubber product vary depending on the materials burned. The major constituents of concern are heavy metals (lead, cadmium, mercury).

On May 2, 1994, the U.S. Supreme Court decided that ash which exhibits a hazardous waste characteristic is a hazardous waste and must be so managed. States may also have special requirements for MSW combustion ash, and readers are urged to check with state environmental programs, because such requirements may impact the feasibility of WTE for some communities.

WTE facility wastewater is another special concern.
(p. 8-36)

Some facilities also generate wastewater. Those considering a WTE facility should anticipate and acquire all permits that are needed for wastewater treatment and disposal. WTE facility wastewater may affect both ground and surface waters.

Local permits are usually required.
(p. 8-36)

The construction and operation of a WTE facility also requires several other permits, many of which satisfy local requirements, such as those for zoning or traffic.

Other environmental concerns must be addressed.
(p. 8-37 — 8-38)

- Noise pollution: Truck traffic, plant operations and air handling fans associated with the combustion and emissions control equipment may produce troublesome noise. Most states have standards for noise levels from industrial facilities. Walls, fences, trees, and landscaped earthen barriers may reduce noise levels.
- Aesthetic impacts: Negative aesthetic impacts can be prevented or minimized by proper site landscaping and design of facility buildings.
- Land use compatibility: WTE plants should be located where they will be considered a compatible or nondisruptive land use. Construction in an industrially zoned area is an example of siting in a compatible land use area. Undeveloped land around the facility will mitigate undesirable impacts.
- Environmentally sensitive areas: Impacts of WTE operations on environmentally sensitive areas should be thoroughly documented in environmental impact statements. Ambient air levels of metals and other substances should be established downwind and in the vicinity of the facility to use as a baseline for measuring future impacts on environmentally sensitive areas.

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Final site selection is based on a detailed environmental and technical evaluation.

(p. 8-38 — 8-40)

The final selection criteria should be based on facility design requirements, including

- adequate land area
- subsoil characteristics to structurally support the facility
- access to water supplies for the process and cooling
- access to required utilities
- access to the energy market.

Sites should also be evaluated for their social and environmental compatibility for the specific facility type:

- compatibility with other land use types in the neighborhood
- evaluation of the area's flora and fauna
- existence of any archaeological sites or protected species at the site.

Deciding how the facility will be managed and by whom is crucial.

(p. 8-40 — 8-41)

Facilities can be managed by public employees or a private contractor. There are several issues to consider when choosing among management options.

- WTE facility management requires a properly trained and well-managed team.
- Daily and annualized maintenance using specialized services and an administrative staff to procure and manage such services are required.
- To be financially successful, a WTE facility must be kept online. The cost to the service area when a facility is out of service can be great; quick action to re-establish service is essential.

The advantages and disadvantages of public vs. private operation must be evaluated.

(p. 8-41)

Public operation—advantages:

- The municipality fully controls the facility's day-to-day operation.
- The municipality gains all the facility's economic revenues from the operation.

Public operation—disadvantages:

- The municipality bears all of the facility's day-to-day problems, costs, and liabilities.

When deciding about public operation, consider these needs.

(p. 8-41)

The following needs should be considered when making a decision about public operation:

- attracting and adequately paying a trained and qualified operating staff
- procuring emergency outage repair services quickly
- maintaining sufficient budgetary reserves to make unexpected repairs
- accepting financial damages from the energy buyer if the facility is unable to provide power according to the energy sales agreement
- assuring bond holders that investments will be well maintained and the facility will operate for the term of the bonds
- finding qualified experts to meet the day-to-day operating demands.

8 ❖ HIGHLIGHTS (continued)

Private operation also has special considerations.
(p. 8-41)

Private operation offsets some of the major operating risks posed by WTE facilities, and there may be a long-term advantage to using the services of a private operating company to operate and maintain the facility.

In choosing a private operator, the municipality relinquishes some of the day-to-day operating control and decisions in plant operations. However, the municipality will gain financial security because the operator will be obliged to pay for the cost of failing to meet specific contract performance obligations between the municipality and the energy buyer.

Financing methods affect project execution.
(p. 8-41 — 8-42)

Project financing can be a very complex process requiring detailed legal and tax issues that need to be carefully reviewed and understood. After deciding to develop a facility, the team should add qualified financial advisors to their staff. Financing alternatives include the following:

- general obligation (G.O.) bonds
- municipal (project) revenue bonds
- leverage leasing
- private financing.

Project execution risks must be properly evaluated.
(p. 8-43)

Constructing and operating a WTE facility requires the participants to carefully consider project execution risks. Major risk issues include the following:

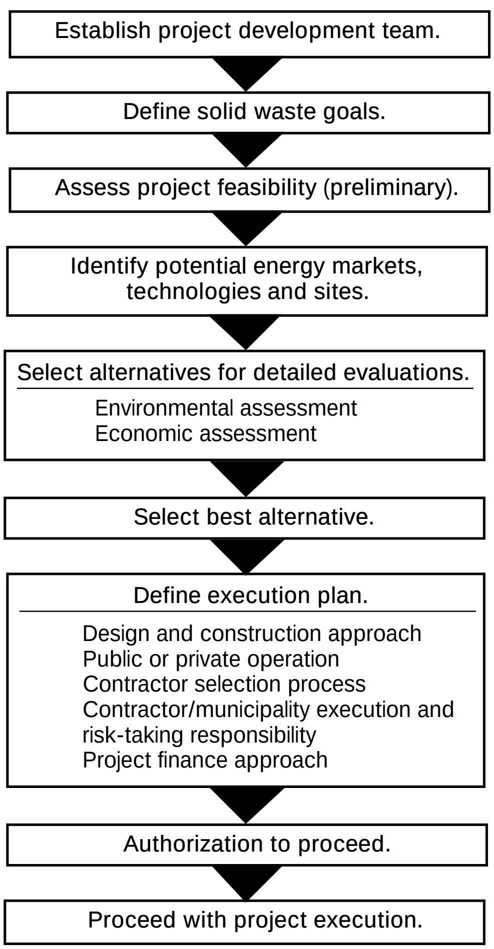
- availability of waste
- availability of markets and value of energy and recovered materials
- facility site conditions
- cost of money (i.e., bond interest rate)
- compliance with environmental standards (short- and long-term)
- waste residue and disposal site availability
- construction cost and schedule
- operating cost and performance
- strikes during construction and operation
- changes in laws (federal, state, and local)
- long-term environmental impact and health risks
- unforeseen circumstances (force majeure)
- long-term operating costs
- long-term performance.

8 COMBUSTION

THE IMPLEMENTATION PROCESS

When contemplating a WTE system, following a systematic evaluation and development procedure is critical to success. Figure 8-1 diagrams such a process. Community leaders considering WTE incineration as part of their integrated waste management plan need to answer several questions: Is WTE a necessary part of their integrated waste management plan? Is energy recovery feasible for the community? If so, how can a project be implemented successfully?

Figure 8-1
Project Definition and Development Plan



Source: G. L. Boley

These questions and many others need to be answered as program developers work through a step-by-step procedure that addresses each major issue involved in facility siting and implementation. Following such a plan will help ensure that important elements are not overlooked and will likely save time and money if issues are addressed at the optimum point in the process. It is important as well to recognize that a WTE project involves developing business-like relationships with several key players, including system vendors, waste producers, haulers, energy buyers, and citizens.

Also, remember that the project will take a number of years to implement, even if no stumbling blocks are encountered. The time frame may be as follows: one year for preliminary planning, including identification of waste sources, energy markets, most appropriate technology and best site; one year to identify the contractor/operator and the financing method; two to three years for development, including negotiating contracts, gaining regulatory agency approval and obtaining financing; and two to three years for facility construction and start up. A small facility may require less time, but many projects have taken even longer to complete than the six to eight years described here.

Project Development Team

Developing and implementing a waste-to-energy project will probably be one of the largest and most complex projects that a municipality undertakes. Making decisions about complex technologies, facility operations, financing, and procurement methods requires assembling a project team whose members can provide many different skills over an extended time.

The project development team provides a broad spectrum of specialized skills over an extended period.

Selecting the development team members is one of the most crucial decisions that program organizers will make. Decisions made at this point will impact the project throughout its development and even into the facility's operating future. Team members should represent all sectors of the community *and* provide the mix of necessary skills required by a complex and highly technical project. Team members may be municipal officials from government public works, finance, legal, and administrative departments, or they may be elected officials. The team can be augmented with experienced consultants who specialize in WTE technologies and project development. The following team members, however, are essential:

- **Project engineer:** Waste-to-energy projects involve many complex technical issues from the initial project evaluation through execution. The first project team member should therefore be a qualified engineer with adequate technical expertise, including facility operations.
- **Financial advisor:** Most WTE projects will require special funding. The financial analyst can assess the most appropriate approach for the community to take. He or she should be involved in the project at the early stages so that the technical work will be coordinated with the financing needs.
- **Attorney:** Contracts must be negotiated between the WTE generator and the participating vendors, waste producers and haulers, energy buyers, and the system operators. The attorney will prepare contracts and work with the engineer and financial analyst to ensure that the legal requirements for permits and bonding are satisfied.
- **Operator:** System design should allow for simple and efficient operation in conjunction with the community's other solid waste management activities. An experienced operations manager involved at the earliest stages of the project can help the team avoid expensive planning and implementation mistakes.
- **Regulatory officials:** While regulatory officials are not formally part of the project team, they should be kept informed of progress from the beginning. Regulatory permits will be required for air pollution, wastewater disposal, ash disposal, and zoning. Since regulatory requirements may drastically affect facility design and operation, regulatory officials should review design proposals and provide advice on a regular basis.

When putting the project team together, keep in mind that having qualified and experienced people will enhance the chances of a successful project. In addition, a well-conceived and well-designed project is essential for securing attractive financing rates. Putting together a good team is well worth the effort it takes.

PROJECT DEFINITION: IDENTIFYING GOALS

Before taking any action regarding a WTE facility, a community should take the time to answer the most important question: What are the goals? By answering this question at the start, managers can plan the project to meet those goals and avoid unnecessary complexities in the process. Deciding which goals are most important is crucial to defining the scope of the project. Determining early on why waste-to-energy is the technology of choice will give the project direction and can head off potential problems as the project unfolds.

ASSESSING PROJECT FEASIBILITY

To determine whether an energy recovery project is a feasible waste management alternative for the community, the following questions should be addressed:

Is a WTE facility appropriate for your community?

- When source reduction, reuse, recycling, composting, and waste-stream growth patterns are taken into account, is the remaining waste stream sufficient to support an energy recovery facility operating at or near capacity over the life of the project?
- Is there a buyer for the energy produced by the energy recovery facility?
- Is there strong political support for a WTE facility?

If the answer to any of these questions is “no,” WTE incineration probably will not work, and other options should be considered.

Assess Political and Citizen Support

Political support is essential.

Developing a waste-to-energy system involves a great number of technical decisions. Political decisions, however, often dictate whether a project is successful. Political leaders and the public must understand the reasons for pursuing this approach to solid waste disposal. Frequently, the cost of a WTE system will exceed current landfilling costs. Explaining why this alternative was chosen is important in order to build a base of political support. Without this political base, energy markets will be more difficult to find, financing will be more expensive or unavailable, and the overall potential for success will diminish.

Political support is important for other reasons, too. First, siting a WTE facility is a long, complicated, and usually expensive undertaking. Unless the community is strongly behind the project from the beginning, its chances of failing are high. Second, a project may involve private partners as energy buyers. Industrial managers may be reluctant to become involved in a project that does not appear to have community support or is controversial. Finally, strong leadership is needed to bring together all of the diverse parties who are involved in a WTE project.

Evaluate Waste Sources

The fuel value of the waste must be determined.

The community’s long-term solid waste generation rates will directly affect the project’s viability and the willingness of local waste haulers to cooperate with the project. To determine if sufficient waste is available to support a resource recovery project, the long-term effects of waste management practices like source reduction, recycling, yard trimmings composting, and also changes in materials use (for example, from glass to plastic bottles) on waste volumes and composition should be considered.

Once the type and quantity of waste have been identified, the amount of recoverable energy can be estimated. This is a preliminary projection, since the particular waste-to-energy technology has not yet been determined. Later, a solid waste composition survey that includes tests for heating value to obtain a more accurate projection may be necessary. See Table 8-2 for heating values of typical solid waste components.

Waste Composition

Any form of solid waste management that alters the waste stream available to a WTE project (by reducing/increasing volumes, removing high- or low-Btu

Table 8-2
Heating Value of Typical Solid Waste Components

Material (BTU)	Composition (in %)	Energy Content (per pound)
Paper	50%	7,700
Food Wastes	10%	1,800
Yard Wastes	15%	4,200
Plastic	2%	17,000
Glass	8%	--
Metal	7%	--
Miscellaneous	8%	1,000
Total	100%	5,080

Source: P. O'Leary, P. Walsh and F. Cross, Univ. of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1987

materials, etc.) must be evaluated for its present and future effects on the project. WTE developers should be aware of any planned or anticipated statutory changes in the regional and local waste handling scheme. An evaluation of changes in the waste stream may include the following:

Changes in waste quantity and characteristics must be anticipated.

- annual range of waste quantities (minimum / maximum waste volumes in a year)
- moisture content
- waste analysis (i.e., heat value, chlorine and sulfur content, etc.)
- quantity of bulky items
- percent of noncombustible materials.

Coordination with Other Waste Management Practices

A significant advantage of waste reduction, regardless of the technique, is that a smaller WTE facility may result. A WTE facility is a long-term investment and the development of that facility should take into consideration other existing or future waste management practices in the service area.

Waste Reduction

"Source reduction" and "reuse" encompass a wide range of techniques for reducing the amount of solid waste that require recycling, incineration, or landfilling. The two basic types of source reduction techniques are those affecting the quantity of waste and those affecting the toxicity of the waste. Both types of source reduction ultimately affect WTE feedstocks.

Waste management practices can affect the volume of available waste — anticipate long-term trends before proceeding.

Source Separation of Nonrecyclable and Hazardous Materials

Some municipal WTE facilities have had problems when certain ash samples failed to pass the USEPA toxicity test (TCLP), which determines the material's likelihood for leaching potentially hazardous components. Ash samples have exceeded allowable concentrations of certain metals, like lead or mercury.

Bulky items are generally prevented from entering the combustion process by the crane operator of the WTE facility. The crane operator, however, cannot always remove every microwave, dryer, or freezer from the tipping floor. The problems and associated dangers that bulky items present are minimized in municipalities that collect these bulky items separately.

Recycling

Recycling benefits the incineration process by removing some noncombustibles (including ferrous, aluminum, and glass) and by allowing a reduction in planned facility size due to reduced waste quantity. Recycling can also increase the average heat value of the WTE feedstock. Nationally, recycling levels for all materials may increase over the next decade. This could impact the availability of feedstock for WTE operations. However, some of the effects of recycling may be offset if the annual increase in per capita solid waste generation continues.

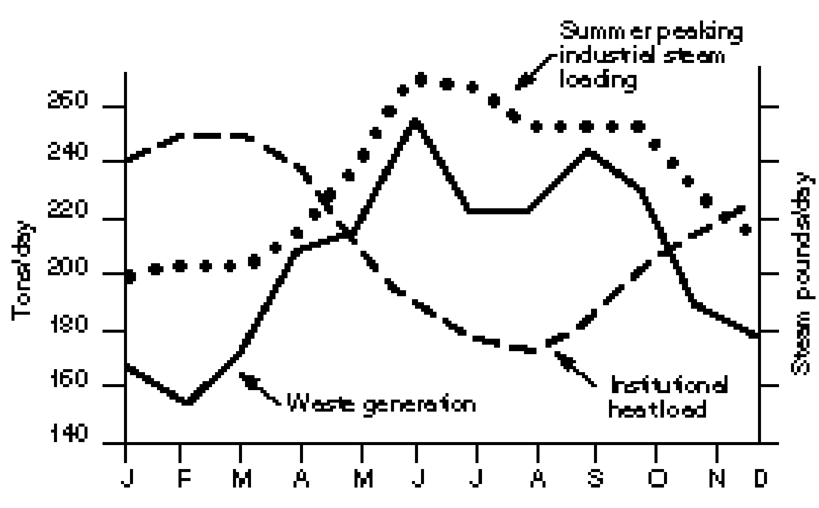
Coordinate recycling and composting planning with combustion system development.

Composting

Municipal yard and food waste composting programs can significantly benefit WTE projects. For example, increases in alternative yard trimmings management programs can reduce seasonal peaks in wet organic matter, which in turn may alter the moisture content and heat value of the feedstock. A decrease in moisture content increases fuel quality by reducing the amount of energy used to vaporize moisture. Thus, by separating or removing wet wastes, the likelihood of creating conditions for optimal boiler temperature and efficiency of energy recovery is increased.

Yard trimmings volumes fluctuate seasonally in temperate zones, with peak quantities occurring from spring to fall. By eliminating or leveling these peaks through other waste management practices, the boiler capacity can be smaller, thereby reducing capital and operation costs (see Figure 8-2).

Figure 8-2
Typical Monthly Waste Generation and Energy Demand Patterns



Source: P. O'Leary, P. Walsh and F. Cross, Univ. of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1987

Landfilling

Landfill availability must be determined.

The WTE facility siting plan should account for proximity to a landfill and current and projected capacity and tipping fees at that landfill. Hauling costs and tipping fees are essential factors in an accurate cost forecast of the WTE facility development process when comparing it to other options. Information on the life span of the landfill, as well as any planned future expansions, should be obtained. Municipal solid waste landfills are necessary for mass-burn as well as RDF processing plants. Incineration can achieve 80 to 90 percent volume reduction in MSW sanitary landfill needs.

What Area Will Be Served?

Establishing the service area is important.

The area served by the WTE system may be established by the governmental body planning the system. For example, a county considering an incinerator to extend landfill life most likely would see the whole county as the service area. The county might also allow limited use by hauling companies that may pick up household wastes just across county lines in normal route operations.

In less populated areas, waste generated within one county may be inadequate to build a facility of a workable size. In such cases, officials may consult with a regional-level authority to assess the feasibility of a facility serving a multi-county area.

In addition, there may be many unanswered questions regarding regional development. In this case, several counties may together fund a study identifying a preliminary plan for developing WTE systems in the region. The study's results could include proposals for the following:

- building one large facility serving the entire region
- building several facilities located strategically to serve the entire region
- building one or more units serving only the region's more populated areas.

A waste inventory for the region to be served is usually the first step. Questions regarding issues such as inter- and intrastate waste transport that may influence communities and waste transporters must then be settled. Then quantity and geographical distribution of wastes available to the facility can be estimated. Taken together, these efforts will provide information on logistics and related costs associated with transporting solid waste to potential facility sites.

ENERGY AND MATERIAL MARKETS

The facility's economic viability depends on significant energy sales.

Because WTE facilities have high capital and operating costs, most need to produce significant income from energy sales to be economically viable. A buyer must be willing and able to enter into a long-term contract to purchase energy at a competitive rate. Low revenues from energy sales must be offset by higher waste tipping fees. When several disposal options are available, the one with the lowest overall life cycle net cost per ton, including transportation and ultimate disposal, usually will be chosen.

Energy Market Options

A WTE facility may generate steam, electricity, super-heated water, or a combination of these. The form of energy produced depends on the energy buyer's needs. WTE facilities usually generate and sell the following marketable products:

- electricity only
- steam only

- co-generation of steam and electricity
- refuse-derived fuel (RDF).

Electricity Only

Electric utilities are attractive markets for power produced by WTE facilities.

Electricity is the most common form of energy produced and sold from WTE facilities constructed today. By directing the WTE system steam through a turbine generator, electricity can be produced and sold. A process flow diagram is shown in Figure 8-3. Since electric utilities can receive power 24 hours a day, seven days a week, and are usually very stable financially, public utilities are very attractive markets for power produced from WTE systems. Under the Public Utility Regulatory Policies Act of 1978, known as PURPA, public utilities must purchase electric power from small power producers and co-generators (those producing both steam and electricity). Section 210 of PURPA exempts small power producers from certain federal and state laws. It also mandates that electric utilities permit small power producers to interconnect and requires utilities to supply back-up power to such facilities at ordinary metered rates.

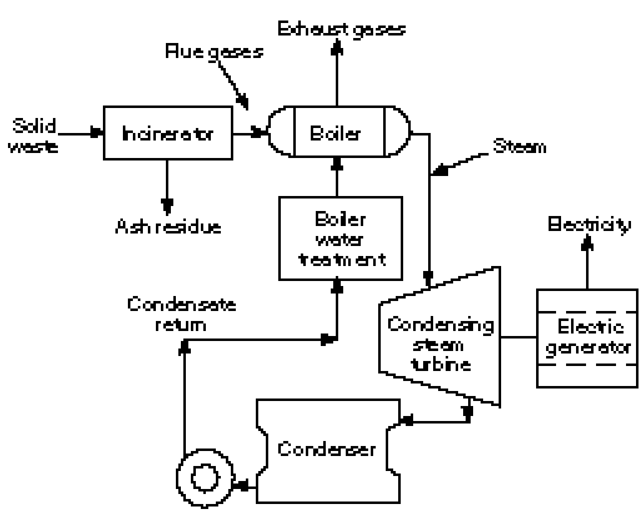
PURPA's most important requirement covers the price utilities must pay to small producers. The law stipulates that utilities must pay such producers at the rate (cents per kilowatt hour) that it would cost the utility to generate the same quantity of electricity, including the avoided cost of any added facilities or equipment. This payment rate, called "avoided cost," is the cost benefit to the utility for receiving electricity from the energy seller. Avoided cost consists of a capital investment component and an operating cost component. Due to local or regional electrical generation practices and electrical demand growth, the avoided cost can vary widely from region to region.

Steam

Steam is used widely in a variety of industrial applications. It can be used to drive machinery such as compressors, for space heating and generating electricity. Industrial plants, dairies, cheese plants, public utilities, paper mills,

Figure 8-3

Incinerator and Electrical Generation System



Source: P. O'Leary, P. Walsh and F. Cross, Univ. of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1987

Marketing steam requires matching available supplies with customers' needs.

tanneries, breweries, public buildings, and many other businesses use steam for heating and air conditioning. The challenge is to match the available supply with prospective customers' needs. Where industrial customers are not available, the use of steam at institutional complexes (a university, hospital, or large office complex) with year-round steam energy needs may be an option.

District heating systems, which provide heat to homes, apartment buildings, and commercial facilities, may also be prime steam customers. A principal disadvantage is that facilities may not be able to efficiently use the energy throughout the entire year since district heating / cooling systems usually have low periods in the spring and fall.

When assessing potential markets for steam, it is important to consider a market's proximity to the WTE facility and the quantity of steam produced. Proximity is important because steam cannot usually be economically transported more than one or two miles; the WTE facility, therefore, should be as close as possible to the potential market. The advantages of transmitting steam over a longer distance to an end user must be weighed against energy losses that will occur in transmission. Installation of a pipeline connecting the facility and the customer can also be prohibitively expensive in certain circumstances. High-temperature hot water may be an option for overcoming the transmission limitation for steam.

Anticipated steam quantity and quality are interrelated parameters, and must be carefully projected when assessing steam markets. The prospective user will most likely have an existing process requiring steam at a specific temperature and pressure. The quantity of steam produced from a given amount of waste will decline as the steam temperature and pressure increases, but the equipment using the steam will also operate more efficiently. To ensure the continuing availability of a high quantity and quality of steam, supplementary fuels, such as natural gas, may occasionally be used, and as a result operating costs may increase.

If the steam price is greater than the cost of energy (i.e., from gas, oil, coal, wood, etc.), and the steam demand is greater than the amount of energy that can be generated from the available waste stream, there may be an economic advantage to increasing the plant size to generate the steam needed by the energy customer.

Co-Generation

Co-generation provides greater energy efficiency, although overall output may be less.

In co-generation, high-pressure steam is used first to generate electricity; the steam leaving the turbine is then used to serve the steam users. Co-generation (See Figure 8-4) provides for greater overall energy efficiency, even though the output of the major energy product, whether electricity or steam, may be less than could be generated by producing one type of energy alone.

Co-generation allows flexibility, so that seasonal variations in steam demand can be offset by increases in electricity production. In addition, PURPA requires that public utilities purchase electricity from co-generators at the utility's avoided cost.

Constructing a multimillion dollar WTE facility to produce only steam for an industrial plant that goes out of business will result in serious financial problems for the WTE facility. Bonding and financing authorities will carefully evaluate the financial health of the energy buyer before agreeing to provide money for the project, and it is important that the energy customer's long-term financial health be assessed early in the energy market analysis. Co-generation can provide the project a financial base by selling electricity should the steam customer become unavailable.

Refuse-Derived Fuel (RDF)

Another form of energy that can be produced and sold is refuse-derived fuel (RDF). RDF is the product of processing the municipal solid waste to separate

RDF is produced from combustible waste and burned in specially designed boilers.

the noncombustible from the combustible portion, and preparing the combustible portion into a form that can be effectively fired in an existing or new boiler. Owners of a WTE facility intending to sell RDF should consider the following:

- nature of the facility that will buy the fuel (i.e., boiler type, fuel fired, etc.)
- projected life and use of that facility by the owner
- facility modifications necessary to accommodate the fuel (including emission control)
- the value of the RDF as a supplemental fuel

RDF can be transported to other locations for use in boilers.

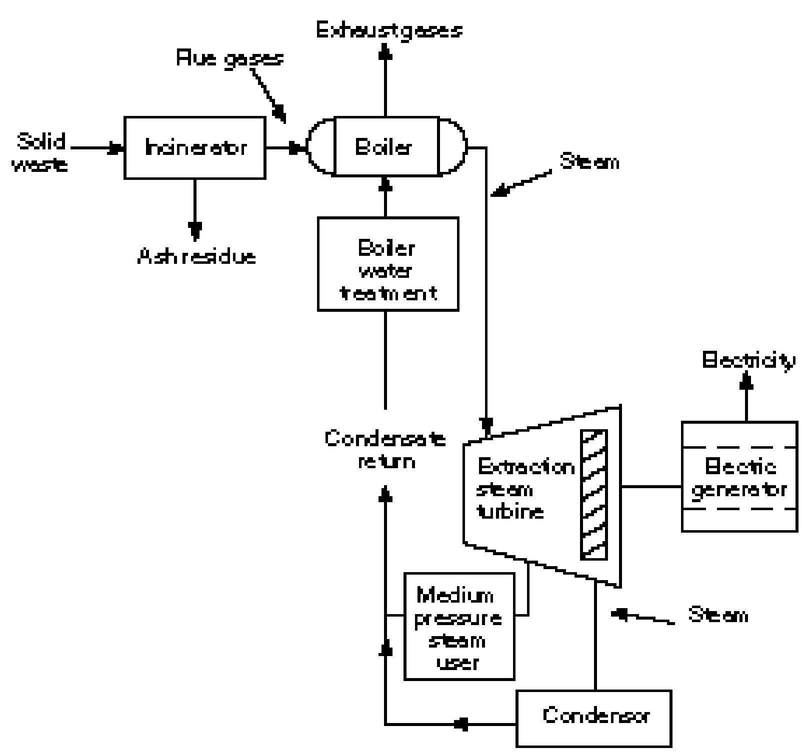
RDF can be produced at a facility some distance from the RDF buyer and transported by truck to the boiler facility. Depending upon the type of combustion facility (i.e., large utility, industrial boiler, etc.) the RDF can be produced in the form of fluff or as densified RDF (D-RDF).

RDF quality (how free the RDF product is of grit, glass, metals, and other noncombustibles) will directly affect a potential user's desire to burn RDF. Where a high-quality RDF product has been developed, burning RDF fuel as a supplemental fuel in existing coal-fired boilers has not created major operational problems.

Coal-burning electric power plants, if appropriately designed or modified, can be a major market for fluff RDF. RDF burned as a replacement for up to 10 percent of the coal in existing utility boilers has been demonstrated to be successful in small projects; higher rates of replacement have been demonstrated in industrial stoker coal-fired steam generators.

Figure 8-4

Co-generation System for Producing Electricity and Steam



Source: P. O'Leary, P. Walsh and F. Cross, Univ. of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1987

Energy Contract Issues

Customers must be assured that using waste-produced energy is equal to or better than using energy from other sources.

In general, finding a market for energy requires initiative. Many opportunities are available for energy sales, but they must be sought out carefully and identified. The prospective customer must be convinced that using energy produced from solid waste is equal to or better than using energy from conventional sources, such as coal, oil, or gas.

Price

The price must be very competitive, usually at a discount compared to the customer's current energy costs. Unless there is some long-term price incentive, the customer may be unwilling to go to the trouble of participating in the project; this is especially true for steam or RDF buyers. The potential energy customer is likely to have a reliable energy source already. Also, the potential customer must somehow recover the administrative costs incurred while becoming involved in a WTE system. Such costs can become substantial when the project is complex or controversial.

Service and Schedule

Timing and reliability are important.

Energy must be available when the customer needs it. Steam and electricity contracts are normally negotiated to be either guaranteed (uninterruptible service) or "as needed or available" (interruptible service). The price received varies according to the type of service. The daily and seasonal demand fluctuations of the customer and the WTE facility must be estimated and taken into account in preparing an agreement. Figure 8-2 shows how waste generation and steam demands of potential users may vary seasonally. In the situation shown, the "Summer Peaking Industrial Steam Load" roughly correlates with the waste generation pattern. However, in the example, the "Institutional Heat Load" is highest when waste generation is the lowest. If waste quantities are insufficient to generate the required steam under an uninterruptible service plan, then the incinerator operator must generate steam with supplemental fuel or pay a penalty. Electrical contracts are usually negotiated on the basis of providing "on-peak" or "off-peak" power. "On-peak" power will be of greater value to the buyer.

Reliability

Anticipated system reliability is also important in developing energy markets. The customer must be assured that the facility can meet its commitments, especially for uninterrupted service. Contracts must state contingency plans for facility shutdown periods.

Material Markets

Sales of recovered materials can be an important revenue source.

In certain situations, more than one market may be available for the recovered products produced by the WTE plant. While these markets alone may not be sufficient to provide enough revenues to make a plant feasible, they can provide valuable additions to plant revenue. For example, sale of recyclable materials may be a source of additional revenue for a WTE project.

Where a vigorous recycling or source-separation program is employed, a plant should be downsized to avoid the additional capital cost of installing extra capacity. WTE facilities that separate paper also have the option of using some of the stored paper to make up for temporary waste volume shortfalls if a guaranteed energy demand must be satisfied, if the paper market is depressed, or if paper is unavailable for a period of time.

Ferrous materials are usually recovered in RDF facilities by magnetic separators as part of the RDF preparation process from mass-burn systems through magnetic separation from the ash. The economic benefit of metal recovery can be two fold: There is the revenue potential from the sale of the product and the avoided cost of hauling and disposing of that material.

THE COMBUSTION PROCESS AND TECHNOLOGIES

Combustion is a chemical reaction in which carbon, hydrogen, and other elements in the waste combine with oxygen in the combustion air, which generates heat.

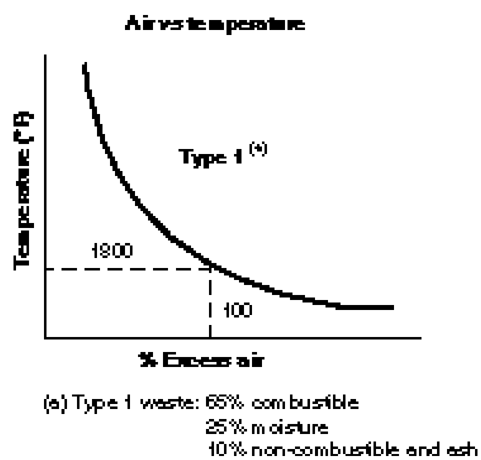
Usually, excess air is supplied to the incinerator in order to ensure complete mixing and combustion. The combustion principle gas products include carbon dioxide, carbon monoxide, water, oxygen, and oxides of nitrogen.

Excess air is also added to the incinerator to regulate operating temperature and control emissions. Excess air requirements will differ with waste moisture contents, heating values, and the type of combustion technology employed.

Many incinerators are designed to operate in the combustion zone at 1,800° F to 2,000° F. This temperature is selected to ensure good combustion, complete elimination of odors, and protection of the walls of the incinerator. A minimum of 1,500° F is required to eliminate odor. As more excess air is supplied to the incinerator, the operating temperature is lowered (see Figure 8-5).

Figure 8-5

Combustion Excess Air Versus Combustion Gas Temperature



Source: P. O'Leary, P. Walsh and F. Cross, Univ. of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1987

WTE systems must be carefully designed to handle a wide range of waste input conditions.

Waste-to-energy systems are designed to maximize waste burn out and heat output while minimizing emissions by balancing the three "T"s:— time, temperature, and turbulence— plus oxygen (air). The heterogeneous nature of municipal solid waste requires that waste-to-energy systems be carefully designed to operate efficiently over a wide range of waste input conditions.

Technology Options

A number of demonstrated technology approaches are available for WTE projects today; the predominate ones are (1) modular incinerators, (2) mass-burning systems, and (3) refuse derived fuel (RDF) systems. Table 8-3 is a summary by state of the operating WTE facilities using mass-burn and RDF technologies.

The technology selection process begins with evaluating all plausible options, considering the quantity and quality of waste, the energy market options available, local environmental considerations, or other local factors that can affect selection decisions.

Modular Systems

Modular combustion systems are usually factory-assembled units consisting of a refractory-lined furnace and a waste heat boiler. Both units can be preas-

Table 8-3

Municipal Waste Combustion and Tires-To-Energy Facilities in the U.S.

State/Plant Name/ Location	Technology Type	Design Capacity*
Alabama		
Huntsville WTE Facility/Huntsville	MB	690
Alaska		
Fairbanks	RDF-P	50
Fairbanks (RDF Market)/ Area Markets (incl. U. of AK)	RDF-C	50
Juneau	INCIN	70
Shemya/Air Force Base	MOD	20
Sitka/Sheldon Jackson College	MOD	50
Arkansas		
Batesville WTE Facility/Batesville	MOD	100
Blytheville	INCIN	70
Osceola	MOD	50
Stuttgart	INCIN	60
California		
Commerce/Los Angeles Co.	MB	380
Long Beach (SERRF)/Long Beach	MB	1,380
Stanislaus/Modesto	MB	800
Southern California Edison/ San Bernardino Co.	RDF	150
Susanville	MB	20
Modesto Energy Project/Westley	TTE	170
Colorado		
Yuma Co./ N/D	N/D	N/D
Conecticut		
Bridgeport	MB	2,250
Bristol Resource Recovery Facility/ Bristol	MB	650
MID-Connecticut RRF/Hartford	RDF	2,000
New Cannan	INCIN	125
Southeastern/Preston	MB	600
Stamford	INCIN	360
Wallingford	MOD	420
Lisbon	MB	600
Exeter/Sterling	TTE	300

State/Plant Name/ Location	Technology Type	Design Capacity
Delaware		
Delaware Reclamation/Newcastle	RDF-P	620
Pigeon Point/Wilmington	MOD	600
Florida		
Bay Co./Panama City	MB	510
Broward Co. North/Pompano Beach	MB	2,250
Broward Co. South/Ft. Lauderdale	MB	2,250
Dade Co./Miami	RDF	3,000
Hillsborough Co. Resource Recovery Facility/Tampa	MB	1,200
Key West/Monroe Co.	MB	150
Lake Co./Okahumpka	MB	528
Lakeland	RDF	300
Mayport Naval Station/Mayport	MOD	50
McKay Bay Refuse to Energy Facility/Tampa	MB	1,000
Miami International Airport/Miami	MOD	60
Pasco Co./Hudson	MB	1,050
Pinellas Co./St. Petersburg	MB	3,000
West Palm Beach Co./ West Palm Beach	RDF	2,000
Lee Co./Fort Meyers	MB	1,200
Dade Co. (Expansion)/Miami	RDF	1,500
Polk Co./Winter Haven	N/D	N/D
Polk Co. TTE Project/Polk Co.	TTE	100
Georgia		
Savannah	MB	500
Atlanta (Tire Market)/ Various Area Markets	TIRE-C	165
Atlanta Waste Recovery/Atlanta	TIRE-P	165
Hawaii		
Honolulu Resource Recovery Venture (H-Power)/Honolulu	RDF	2,160

– Table 8-3 continued on following pages –

*Tons per day

Technology Abbreviations

INCIN = MWC with no energy recovery.
MB = Mass burn (MWC typically with a single combustion chamber, constructed on-site, with energy recovery).
MOD = MWC typically with two-stage combustion, shop fabrication, field erection, and with energy recovery.
MWC = Municipal waste combustor; includes both WTE plants and incinerators.
RDF = Facility with extensive front-end waste processing and dedicated boiler for combusting prepared fuel on site.
RDF-P = Municipal waste processing facility generating a prepared fuel for off-site combustion.
RDF-C = Combustion facility typically capable of burning more than one fuel (e.g., RDF and coal).
TTE = Tires-to-energy. Tire waste combustor with energy recovery.
TIRE-P = Tire waste processing facility generating a prepared fuel for off-site combustion.
TIRE-C = Combustion operation typically capable of burning more than one type of fuel.
WTE = Waste-to-energy. (Municipal waste combustor with energy recovery. In this table, WTE includes MB, MOD, RDF, and RDF Combustion systems.)

Source: IWSA (Integrated Waste Services Association), *The IWSA Municipal Waste Combustion Directory: 1993 Update of U.S. Plants*, 1993

Table 8-3—continued from previous page

Municipal Waste Combustion and Tires-To-Energy Facilities in the U.S.

State/Plant Name/ Location	Technology Type	Design Capacity
Illinois		
Chicago NW/Chicago	MB	1,600
Crestwood (USA Waste RDF Market)/Crestwood	RDF-C	125
USA Waste of IL., Inc./Crestwood	RDF-P	125
Beardstown/Cass Co.	RDF	1,800
Havana WTE Facility/Havana	RDF	1,800
Rantoul	N/D	N/D
Robbins	RDF	1,600
West Suburban Recycling and Energy Center/Village of Summit	RDF	1,800
Ford Heights	TTE	200
Indiana		
Indianapolis	MB	2,362
Monroe Co./Bloomington	MB	300
Sullivan Co./Fairmount	RDF	3,000
Iowa		
AG Processing (Iowa Falls RDF Market)/Eagle Grove	RDF-C	75
Ames	RDF-P	200
Ames Municipal Electric Utility (RDF Market)/Ames	RDF-C	150
Iowa Falls	RDF-P	75
Kentucky		
Kentucky Energy Associates/Corbin	MB	500
Maine		
Harpswell/South Harpswell	INCIN	14
Maine Energy/Biddeford - Saco	RDF	750
Mid-ME Waste/Auburn	MB	200
Penobscot Energy Recovery Company/Orrington	RDF	1,000
Portland	MB	500
Easton	N/D	N/D
Maryland		
Hartford Co./Aberdeen Proving Grounds (Army)	MOD	360
Pulaski/Baltimore	INCIN	1,200
Southwest Resource Recovery Facility (BRESCO)/Baltimore	MB	2,250
Montgomery Co./Dickerson	RDF-P	1,200
Baltimore Co./Cockeysville	RDF-P	1,200
Carroll Co./Westminster	N/D	N/D
Fort Meade/Anne Arundel Co.	N/D	N/D
Hartford Co. (Expansion)/ Aberdeen Proving Grounds (Army)	MOD	125
Massachusetts		
Central Mass. Resource Recovery Project/Millbury	MB	1,500
Fall River	INCIN	600
Haverhill (MB)/Haverhill	MB	1,600
Haverhill (RDF)/Haverhill	RDF-P	900
Haverhill (RDF market)/Lawrence	RDF-C	710
Mass. Refusetech/North Andover	MB	1,500
Pittsfield Resource Recovery Facility/Pittsfield	MOD	240
Saugus RESCO/Saugus	MB	1,500
Massachusetts, cont'd		
SEMASS/Rochester	RDF	2,700
Springfield RRF/Agawan	MOD	360
Mass. Regional Recycling Facility/Shirley	MB	243
Michigan		
Central Wayne Co./Dearborn Heights	INCIN	500
Greater Detroit Resource Recovery/Detroit	RDF	3,300
Jackson Co. Resource Recovery Facitliy/Jackson	MB	200
Kent Co./Grand Rapids	MB	625
Oakland Co./Auburn Hills	MB	2,000
Southeast Oakland Co./ Madison Heights	MB	600
Michigan TTE Project/Albion	TTE	N/A
Minnesota		
Eden Prairie/Hennepin Co.	RDF-P	560
Elk River Resource Recovery Facility/Anoka Co.	RDF	1,500
Fergus Falls RRF/Fergus Falls	MOD	94
Hennepin RRF/Minneapolis	MB	1,200
Olmstead Co. WTE Facility/ Rochester	MB	200
Perham Renewable Resource Facility/Perham	MOD	100
Polk Co. Solid Waste Recovery Facility/Fosston	MOD	80
Pope-Douglas Solid Waste/Alexandria	MOD	72
Ramsey-Washington/Newport	RDF-P	1,200
Ramsey-Washington (Newport RDF Market)/Red Wing	RDF-C	720
Red Wing Solid Waste Boiler Facility/Red Wing	MOD	72
Richard's Asphalt/Savage	MOD	80
Thief River Falls	RDF-P	100
Thief River Falls (TRF RDF Market)/ Northwest Medical Center	RDF-C	100
Western Lake Superior Sanitary District (WLSSD)/Duluth	RDF	400
Wilmarth Plant (Eden Prairie and Newport RDF Market)/Mankato	RDF-C	720
Mississippi		
Pascagoula ERF/Moss Point	MOD	150
Missouri		
St. Louis	RDF	1,200
Montana		
Livingston/Park Co.	INCIN	72
Nevada		
Moapa Energy Project/Moapa	TTE	N/D
New Hampshire		
Auburn	INCIN	5
Candia	INCIN	15
Claremont	MB	200

– Table 8-3 continued on following pages –

Table 8-3—continued from previous page

Municipal Waste Combustion and Tires-To-Energy Facilities in the U.S.

State/Plant Name/ Location	Technology Type	Design Capacity
New Hampshire, cont'd		
Concord Regional Solid Waste Recovery Facility/Concord	MB	50
Durham/University of New Hampshire	MOD	108
Lincoln	INCIN	24
Litchfield	INCIN	22
Nottingham	INCIN	8
Pelham	INCIN	24
Plymouth	INICN	16
Wilton	INCIN	30
Wolfeboro	INCIN	16
New Jersey		
Camden Resource Recovery Facility/Camden	MB	1,050
Essex Co. Resource Recovery Facility/Newark	MB	2,505
Fort Dix	MOD	80
Gloucester Co./Westville	MB	575
Warren RRF/Oxford Township	MB	400
Union Co./Rahway	MB	1,440
Mercer Co./Duck Island	MB	1,450
New York		
Albany Steam Plant (ANSWERS RDF Market)/Albany	RDF-C	600
ANSWERS Project/Albany	RDF-P	800
Babylon Resource Recovery Facility/Babylon	MB	750
Dutchess Co./Poughkeepsie	MB	506
Hempstead/Westbury	MB	2,505
Henry Street, Brooklyn/NY City	INCIN	1,000
Huntington RRF/E. Northport	MB	750
Islip (MacArthur Energy Recovery)/ Ronkonkoma	MB	518
Kodak/Rochester	RDF	150
Long Beach Recycling and Recovery Corp./Long Beach	MB	200
Niagara Falls	RDF	2,000
Oneida Co./Rome	MOD	200
Oswego Co./Fulton	MOD	200
Saltaire/Fire Island	INCIN	12
Washington Co./Hudson Falls	MB	450
Westchester Co./Peekskill	MB	2,250
Onondaga Co.	MB	990
Albany Port Ventures/Port of Albany	MB	1,300
Bay 41st St., Brooklyn SW/NY City	INCIN	1,050
Brooklyn Navy Yrd/NY City	MB	3,000
Capital District/Green Island	MB	1,500
Cattaraugus Co./Cuba	MOD	112
Glen Cove	MB	250
Islip (MER Expansion)/Ronkonkoma	MB	350
West Finger Lakes/Four Area Counties	N/A	550
North Carolina		
New Hanover Co./Wilmington	MB	450
University City RRF/Mecklenburg Co.	MB	235
BCH Energy Limited/Fayetteville	RDF	1,200
Arrowood/Mecklenburg Co.	MB	600
Carolina Energy/Chatam Co.	RDF	1,200
Ohio		
Akron	RDF	1,000
Columbus	RDF	2,000
Montgomery Co. North/Dayton	MB	300
Montgomery Co. South/Dayton	INCIN	900
Mad River Energy Recovery/ Springfield	MB	1,750
Stark Recycling Center/Canton	RDF-P	N/A
Oklahoma		
Miami	MOD	108
W.B. Hall Resource Recovery Facility/Tulsa	MB	1,125
Oregon		
Coos Bay/Coquille	INCIN	100
Marion Co./Brooks	MB	550
Portland	TIRE-P	100
Portland (Tire Market)/ Various Area Markets	TIRE-C	100
Pennsylvania		
Delaware Co./Chester	MB	2,688
Harrisburg	MB	720
Lancaster Co. RRF/Bainbridge	MB	1,200
Montgomery Co./Conshohocken	MB	1,200
Westmoreland Co./Greensburg	MOD	50
York Co./Manchester Township	MB	1,344
Falls Township-Wheelabrator/ Falls Township	MB	1,600
Falls Township-Technochem/ Morrisville	MOD	70
Glendon	MB	500
West Pottsgrove/Berks Co.	MB	1,500
Puerto Rico		
San Juan	MB	1,200
South Carolina		
Chambers Development/Hampton	MOD	270
Charleston/Charleston Co.	MB	600
Tennessee		
Nashville	MB	1,120
Robertson Co. Recycling Facility/ Springfield	RDF-P	50
Springfield (RDF Market)/ Various Area Markets	RDF-C	50
Sumner Co./Gallatin	MB	200
Texas		
Carthage Co.	MOD	40
Cass Co./Linden	RDF-P	-200
Cass Co. (Linden RDF Market)/ International Paper	RDF-C	-120
Center	MOD	40
Cleburne	MOD	115
Baytown	TIRE-P	165
Baytown (Tire Market)/ Various Area Markets	TIRE-C	165
Utah		
Davis Co./Layton	MB	400

– Table 8-3 continued on following page –

Table 8-3—continued from previous page

Municipal Waste Combustion and Tires-To-Energy Facilities in the U.S.

State/Plant Name/ Location	Technology Type	Design Capacity
Vermont		
Readsboro	INICN	13
Stamford	INCIN	10
Rutland	MOD	240
Virginia		
Alexandria - Arlington/Alexandria	MB	975
Arlington/Pentagon	INCIN	50
Fairfax Co./Lorton	MB	3,000
Galax	MOD	56
Hampton	MB	200
Harrisonburg Resource Recovery Facility/Harrisonburg	MB	100
Salem	MOD	100
Southeastern Public Service Authority of Virginia/Portsmouth	RDF	2,000
Fort Eusits/Newport News		
Prince William Co./Prince William	MB	1,700
Washington		
Bellingham/Ferndale	MOD	100
Skagit Co. Resource Recovery Facility/Mt. Vernon	MB	178
Washington, cont'd		
Spokane Regional Solid Waste Disposal Facility/Spokane	MB	800
Tacoma (City Landfill)/Tacoma	RDF-P	500
Tacoma (RDF Market)/Tacoma	RDF-C	300
Fort Lewis	MB	120
Wisconsin		
Barron Co./Almena	MOD	80
LaCrosse Co./French Island	RDF	400
St. Croix WTE Facility/New Richmond	MOD	115
Madison	RDF-P	250
Madison (Power Plant - RDF Market)/ Madison Gas & Electric	RDF-C	400
Marathon Co./Ringle	RDF-P	200
Marathon Co. (Ringle RDF Market)/ Area Paper Mills	RDF-C	500
Muscoda	MOD	120
Waukesha	MB	175
Winnebago Co.	N/D	500–1,000

** End of Table 8-3 **

Source: IWSA (Integrated Waste Services Association), *The IWSA Municipal Waste Combustion Directory: 1993 Update of U.S. Plants*, 1993

Modular systems may be more cost-effective for smaller-sized facilities.

Pre-fabrication and assembly can lower construction costs.

sembled and shipped to the construction site, which minimizes field installation time and cost.

Modular systems are typically in the 15 to 100 ton-per-day capacity range. Facility capacity can be increased by adding modules, or units, installed in parallel to achieve the facility's desired capacity. For example, a 200 ton-per-day facility may consist of four, 50-ton-per-day units or two, 100 ton-per-day units. The number of units may depend on the fluctuation of waste generation for the service area and the anticipated maintenance cycle for the units.

Combustion is typically achieved in two stages. The first stage may be operated in "starved air" or in a condition in which there is less than the theoretical amount of air necessary for complete combustion. The controlled air condition creates volatile gases, which are fed into the secondary chamber, mixed with additional combustion air, and under controlled conditions, completely burned. Combustion temperatures in the secondary chamber is regulated by controlling the air supply, and when necessary, through the use of an auxiliary fuel. The hot combustion gases then pass through a waste heat boiler to produce steam for electrical generation or for process or heating purposes. The combustion gases and products of combustion are processed through air emission control equipment to meet the required federal and state emission standards.

In general, modular combustor systems are a suitable alternative and may, for smaller-sized facilities, be more cost-effective than other combustor alternatives. Because of the nature of these facilities, energy production per million Btu of heat input or plant efficiency will likely be lower than alternative combustion technologies. Because of their relative size, modular combustors and waste heat boilers can be factory-assembled or fabricated and delivered, minimizing field erection time and cost.

Mass-Burning Systems

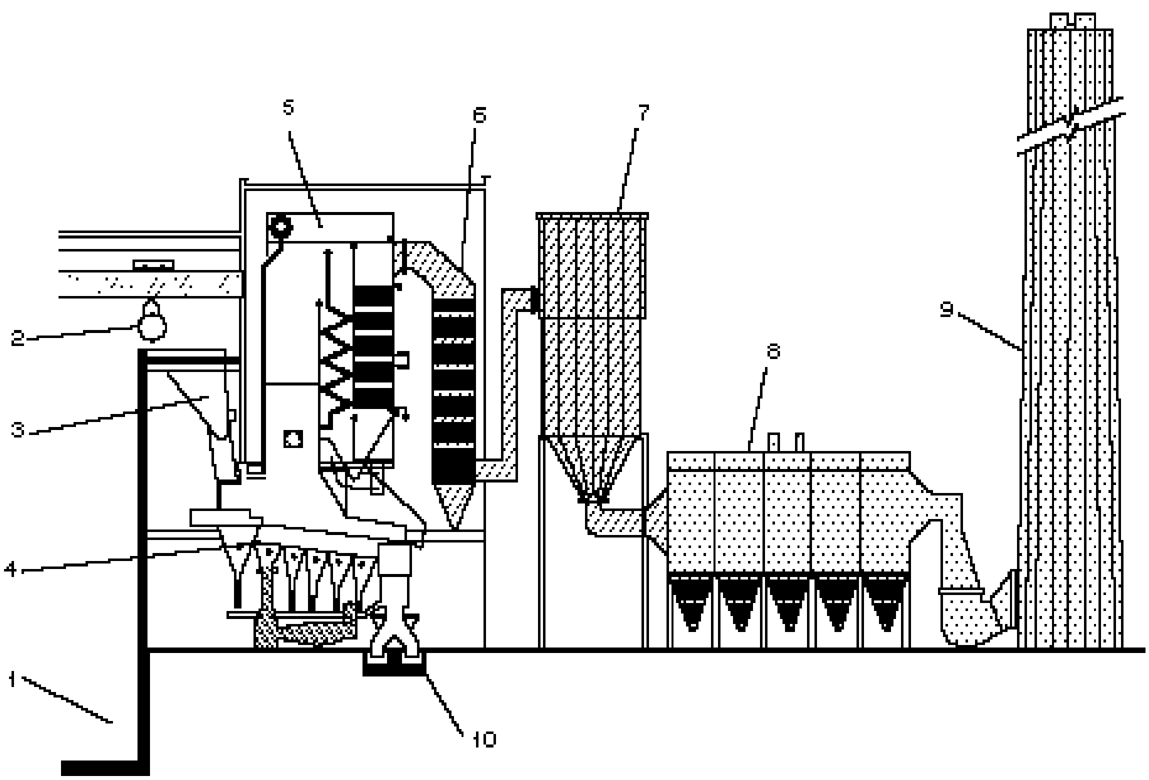
Mass-burning systems have larger capacities and higher thermal efficiencies.

A mass-burn WTE facility typically consists of a reciprocating grate combustion system and a refractory-lined, waterwalled, steam generator. Today a typical facility consists of two or more combustors with a size range of 200 to 750 tons-per-day each. Because of the larger facility size, the combustor is more specially designed to efficiently combust the waste to recover greater quantities of steam or electricity for export as a revenue source (see Figure 8-6).

To achieve this greater combustion and heat recovery efficiency, the larger field-erected combustors are usually in-line furnaces with a grate system. The steam generator generally consists of refractory-coated waterwall

Figure 8-6

Typical Mass-Burn Facility Schematic



1. Receiving Pit
2. Charging Crane
3. Feed Hopper
4. Grate System
5. Steam Generator
6. Heat Exchanger
7. Acid Gas Spray Dry Scrubber
8. Particulate Collection
9. Stack
10. Ash Quench/Removal

Source: Combustion Engineering, Inc., Windsor, Connecticut, 1990

systems with walls comprised of tubes through which water circulates to absorb the heat of combustion. In a waterwall system, the boiler is an integral part of the system wall, rather than a separate unit as is in a refractory system.

Mass burning of waste can also be achieved by the use of a rotary kiln. Rotary kilns use a turning cylinder, either refractor or waterwall design, to tumble the waste through the system. The kiln is declined, with waste entering at the high elevation end and ash and noncombustibles leaving at the lower end. Rotary combustors may be followed by a traveling or reciprocating grate to further complete combustion.

A typical facility consists of two or more combustors that are sized to properly fire or burn the area's municipal solid waste during its peak generation period. Typically, at least two combustor units are included to provide a level of redundancy and to allow waste processing at a reduced rate during periods of scheduled and unscheduled maintenance.

Mass-burn systems generate a higher-quality steam, allowing for higher revenues per ton of waste.

Mass-burn facilities today generate a higher quality steam, (i.e., pressure and temperature) compared to modular systems. This steam is then passed through a once-through turbine generator to produce electricity or through an extraction turbine to generate electricity and provide process steam for heating or other purposes. Higher steam quality allows the use of more efficient electrical generating equipment, which, in turn, can result in a greater revenue stream per ton of waste.

Refuse-Derived Fuel (RDF) Systems

RDF technology has benefitted from past experience and is now considered a "proven technology."

The early RDF projects, developed in the 1970s, were intended to produce a fuel to be used in existing utility or industrial steam generators with little or no modifications to the fuel combustor or its auxiliary equipment. Several projects were developed, but few of those projects are operating today (see Table 8-4).

The predominate RDF systems operating today have incorporated the lessons from the earlier projects and are now considered a proven technology. There are two primary types of systems in operation: the shred-and-burn systems with minimal processing and removal of noncombustibles, and simplified process systems that remove a significant portion of the noncombustibles. Each of these systems uses a dedicated combustor to fire the RDF to generate steam (see Table 8-5).

Table 8-4

RDF Production and Co-Firing Experience

Process Plan			
Location	Design Capacity (tons/day)	Average RDF Production (tons/day)	Status
Ames	200	175	Operating
Baltimore	1200	58[a]	Operating[e]
Bridgeport	1800	N/A[d]	Closed[c]
Chicago	2000	300	Closed[c]
Lakeland	300	270	Operating
Madison	200	120[b]	Closed[f]
Milwaukee	1200	480-880	Closed[c]
Rochester	2000	400	Closed[ac]
St. Louis	200	185	Closed[c]

a = Process operated for short term. RDF was not fired.
b = RDF markets have not been able to utilize full production.
c = Closed after limited operation.
d = Consistent operation not achieved.
e = Burning discontinued in 1989.
f = Closed 12/31/92; RDF market for electrical generating demand significantly reduced.

Source: June, 1988 *EPRI Report*, Updated by ABB-RRS June, 1991

Table 8-5
Dedicated RDF Boiler Facilities

Shred-and-Burn Systems	Daily Capacity	Started Operation
Akron, OH*	1000	1979
ANSWERS (Albany, NY)	600	1981
Hooker Chemical (Niagara Falls, NY)*	2000	1981
SEMASS (Rochester, MA)	1800	1988

**Process modified to shred-and-burn technology*

Simplified Process Systems

	Coal Co-firing	Daily Capacity	Started Operation
Dade County, FL	No	3000	1982/1989**
Columbus, OH	Yes	2000	1982
Duluth, MN	No	400	1985***
MERC (Saco/Biddeford, ME)	No	600	1987
Ramsey/Washington City, MN	No	1000	1987
LaCrosse County, WI	No	400	1987****
Mid-Connecticut (Hartford, CT)	Yes	2000	1988
PERC (Orrington, ME)	No	1000	1988
Palm Beach County, FL	No	2000	1989
Anoka County, MN	No	1500	1989
H-POWER (Honolulu, HI)	No	2160	1990
Greater Detroit, MI	No	3300	1990
Tacoma, WA	No	300	1990***

** *Process system modified* *** *Used fluidized bed combustors*
**** *RDF and wood; fluidized bed combustor*

Source: G. L. Boley. "Refuse-Derived Fuel (RDF)—Quality Requirements for Firing in Utility, Industrial, or Dedicated Boilers," International Joint Power Generation Conference, San Diego, CA. October, 1991

Shred-and-Burn Systems

Shred-and-burn systems require minimal removal of noncombustible waste.

Shred and burn systems are the simplest form of RDF production. The process system typically consists of shredding the municipal solid waste to the desired particle size, magnetic removal of ferrous metal, with the remaining portion delivered to the combustor. There is no attempt to remove other noncombustible materials in the municipal solid waste before combustion. The municipal solid waste is shredded to a particle size that allows effective feeding to the combustor. Most systems operate the process system continuously, i.e., there is minimal RDF storage before being fed to the combustor.

Simplified Process Systems

With simplified process systems, a significant portion of noncombustibles is removed.

A simplified process system involves processing the municipal solid waste to produce an RDF with a significant portion of the noncombustibles removed before combustion. The municipal solid waste process removes more than 85 percent of the ferrous metals, a significant percentage of the remaining noncombustibles (i.e., glass, nonferrous metals, dirt, sand, etc.), and shreds the material to a nominal particle top size of 4 to 6 inches to allow effective firing in the combustion unit.

Early RDF process systems relied on air classification as the means to separate the combustible fraction from the noncombustibles. Recent systems rely on screening or trommeling to separate the noncombustibles from the fuel portion. Depending on the type of combustor to be used, a significant degree of separation can be achieved to produce a high-quality RDF (i.e., low ash), which typically results in the loss of a higher percentage of combustibles when compared to systems that can produce a low-quality fuel (i.e., slightly higher ash content) for firing in a specially designed combustor. These types of systems recover over 95 percent of the combustibles in the fuel fraction (see Figure 8-7).

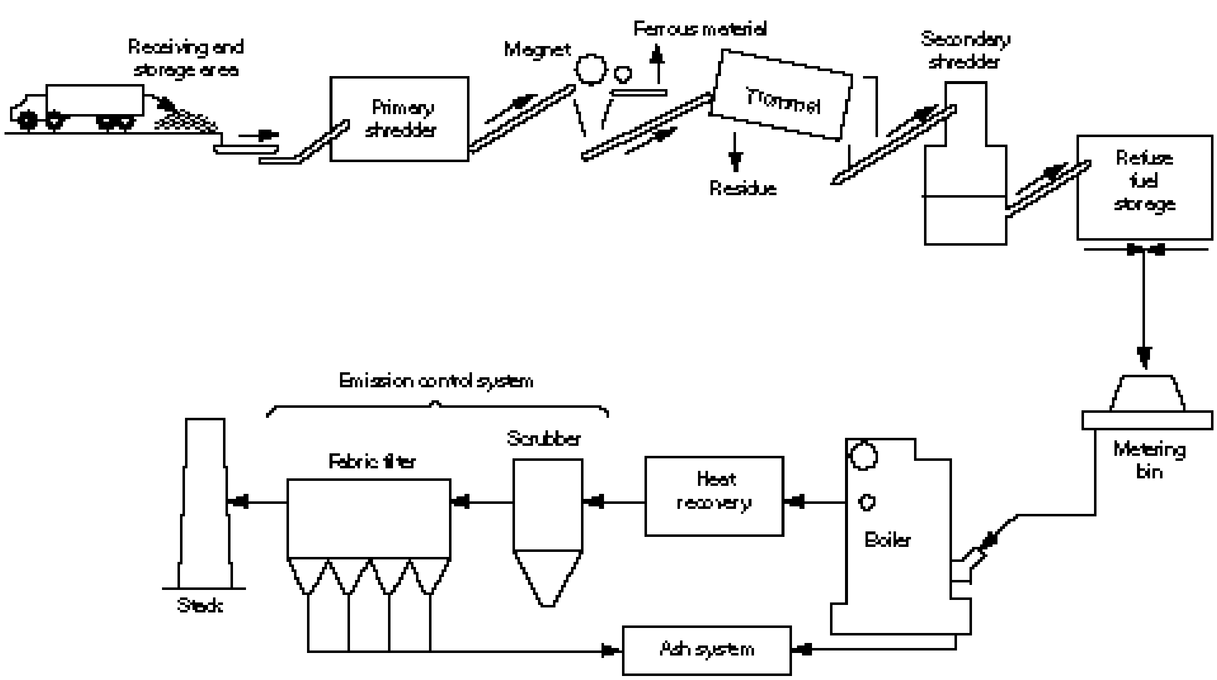
RDF Combustors

RDF fuel is conveyed, transported, and stored more readily than waste itself.

Because the municipal solid waste is transformed into a fuel that can be handled (conveyed, transported, temporarily stored, etc.) more readily than municipal solid waste itself, there are several possible combustor options, including the following.

- **Dedicated Combustor.** This is the most common type of combustor; it is in use at several facilities in the United States. A dedicated RDF combustor consists of a stoker-fed traveling grate and a waterwall steam generator. Unlike the mass-burn combustor, there is no refractory in the lower combustion zone of the combustor. The waterwall tubes are exposed to the combustion gases and radiant heat. The lower furnace is subject to corrosive attack, which can be controlled by using special corrosion resistant metal coatings. The RDF is fired through an air-swept spreader above the traveling grate and is partially burned in suspension with the larger and heavier particles burned on the grate. Combustors range in size from 500 tons-per-day of RDF to as large as 1500 tons-per-day. This

Figure 8-7
Typical Simplified RDF Facility Schematic



Source: Combustion Engineering, Inc., Windsor, Connecticut, 1990

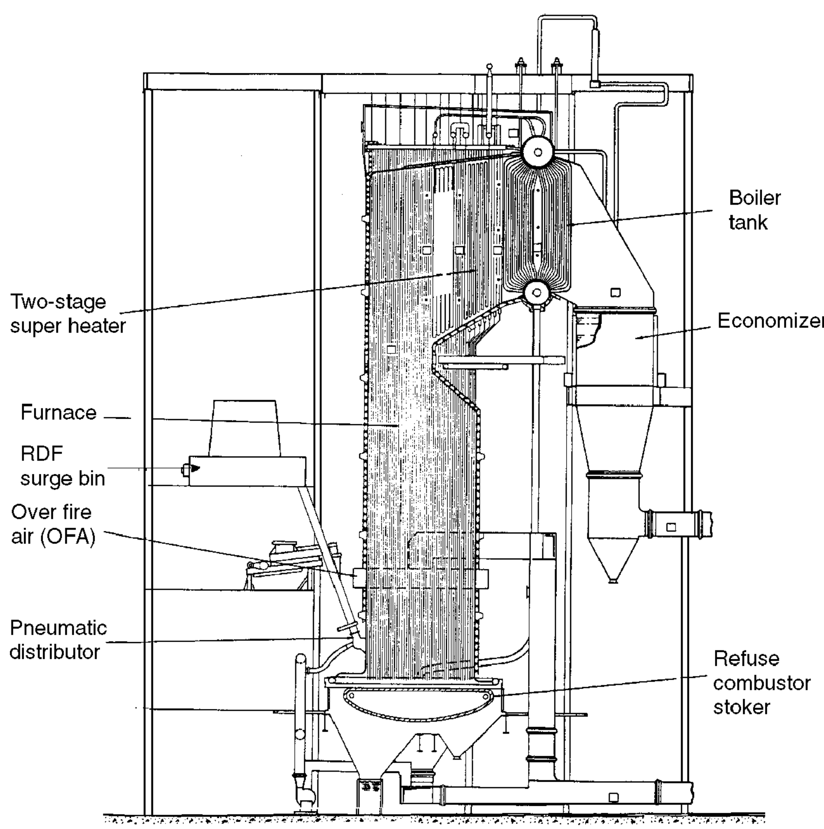
System options must be carefully considered.

technology is comparable to systems used to combust many biomass fuels such as wood, waste, bark, bagasse, and others (see Figure 8-8).

- **Fluidized Bed Combustion.** Fluidized bed combustors for RDF are a relatively new approach involving the firing of the RDF into a bed of fluidized inert noncombustible, high melting-point material (sand) that substitutes for a grate. The RDF is combusted in the suspended sand bed. This improves the combustion reaction by bringing the waste in direct contact with the bed of material. Above the fluidized bed is a waterwall boiler where the heat is transferred to produce steam. Fluidized bed combustion can be an attractive alternative because a wide variety of materials can be burned, including high-moisture content materials such as sludge. In addition, because the units should operate at lower excess air conditions, they can be relatively smaller in size when the emission control equipment is included. This type of combustor has been used less to burn RDF than the dedicated stoker-fired combustors.
- **Co-firing RDF with Coal or Other Biomass Fuels.** Dedicated RDF combustors can co-fire coal, wood waste, or other solid fuels. This may be an advantage if the waste generation rates vary widely by season or as a result of other waste management practices (recycling, waste reduction, pollution prevention, etc.). The facility can remain a stable source of steam or electricity if other fuels can be fired along with or independent of waste.

Figure 8-8

Typical RDF Stoker and Boiler



Source: Combustion Engineering, Inc., Windsor, Connecticut, 1990

- **Densified RDF (D-RDF).** D-RDF is a fuel produced by compressing already processed RDF into cubes or pellets. The increased cost of processing may be offset by allowing for more cost-effective transportation and temporarily storing the fuel product. This fuel type may also be more cost effectively fired into an existing industrial-type boiler firing stoker coal or other solid fuels.

Incinerator System Components

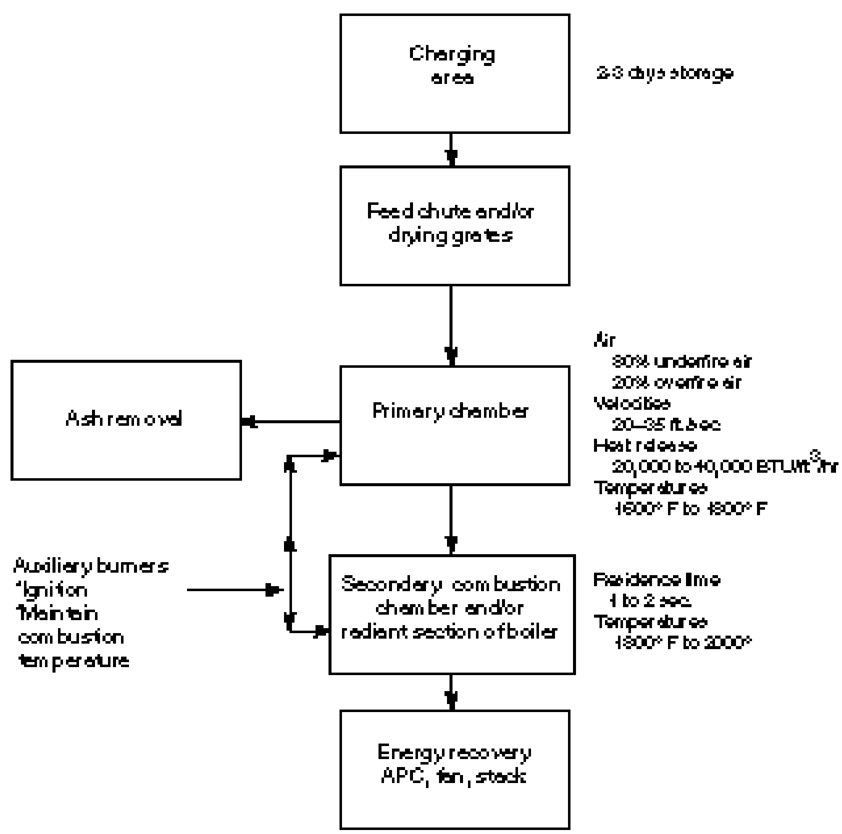
The components must be carefully integrated into a system.

Modular and mass-burn systems receive, store, and fire municipal solid waste without preprocessing or preseparation before firing into the combustor. RDF systems include a level of preprocessing and / or separation of noncombustibles before firing into the RDF combustor. Each of these options have many common components or design features to properly receive and process the municipal solid waste and the resulting products and residues.

Waste-burning facilities with energy recovery generally have the following components: waste storage and handling equipment, combustion system, steam / electrical generator, emission control system, and residual control system. Figure 8-9 shows an example design for a large-scale mass-burning WTE facility.

Figure 8-9

Typical Mass-Burn System Design Basis



Source: P. O'Leary, P. Walsh and F. Cross, Univ. of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1987

Storage and Handling Area

Tipping facilities for handling and storing waste must be sized correctly.

The solid waste storage and handling area consists of either a large tipping floor or tipping pit onto which waste is discharged directly from collection vehicles.

The tipping floor and tipping pit are usually enclosed in a building to control wind and odor problems, as well as to keep precipitation from increasing the moisture content of the waste. This area should be large enough to handle at least three to five days' waste generation volume. This additional space allows for waste storage during weekends, plant outages, and periods of heavy precipitation, when incinerator loadings may need to be reduced to allow for proper burning of wet waste.

A large waste-tipping floor or pit also facilitates the operator in mixing the waste (i.e., dry stored waste may be mixed with incoming wet waste after a rainfall). This results in a more uniform heat feed rate into the furnace. For facilities with a tipping floor, waste is normally pushed into the furnace using a small tractor. At a facility with a tipping pit, a crane lifts the waste from the pit and drops it into a hopper. When loading the furnace, plant operators normally remove large, bulky noncombustible items from the furnace feedstock.

Waste Combustion System

After being fed into the charging system or hopper, the waste is moved into the furnace either by gravity or with a mechanical feeder. Primary combustion occurs in this first chamber. Within the furnace, the waste is agitated and moved to the discharge end by grates, rams, or other equipment and is concurrently mixed with air to achieve maximum burn out.

During incineration, energy is released in the form of heat. Burned material and noncombustibles move downward through the furnace for removal by the ash handling system.

Energy Conversion and Use

Heat released during incineration is transferred to water that is circulated in the boiler tubes, where the energy is absorbed and steam produced. A variety of boilers, heat exchangers, and superheaters are available. The selection of specific units depends on the quality (temperature / pressure) and use of the steam. The steam temperature and pressure produced must satisfy the energy customer's needs and be able to efficiently produce its marketable products: steam and electricity.

Residue Control

Ash handling is an important design element.

The products of combustion include the combustor bottom ash and fly ash. The bottom ash includes the heavy noncombustible materials (i.e., ferrous and nonferrous metals, glass, ceramics, etc.), and ash residues from the combustible material. Bottom ash is normally cooled by quenching in water and then moved by a conveyor system to a temporary storage and truck load-out area. The lighter products of combustion and products collected in the emission control equipment are collected and transported in totally enclosed conveyors to a water-conditioning area to moisten the fly ash residue products and then discharged onto the bottom ash conveyor for truck load-out. Depending on the facility's size and other economic factors, the ferrous metals in the bottom ash can be removed for recycling by magnetic separation. Some new systems can recover nonferrous metals as well.

Emission Controls

In the last 10 years, significant advancements have been achieved in controlling emissions from WTE facilities, including improved combustion controls

Controls for particulates and acid gas are required — heavy metal controls may be required in the future.

and advanced acid gas and particulate emission controls. In the past, incinerator emission control was achieved with electrostatic precipitators to collect particulates. At the time, no other controls were anticipated. Today, however, WTE facilities incorporate not only particulate controls, but also acid gas, organics, and nitrous oxide (NO_x) controls. These new controls have resulted from a better understanding of the potential environmental impacts of waste combustor emissions; municipal solid waste composition; and the effects of uncontrolled emissions of acid gas constituents (i.e., sulfides and chlorides), organics and heavy metals.

Volatile Organic Controls

Volatile organics can be controlled with good combustion practices (i.e., controlling combustion air, municipal solid waste feed rate, and combustion temperature and residence time). The advancements in interactive control instrumentation have made it possible to more closely monitor the combustion process and adjust the municipal solid waste feed rate and combustion air to ensure volatile organic containment (VOC) destruction.

Nitrous Oxides (NOx) Controls

Air emission controls are an integral system element.

NO_x (gaseous oxides of nitrogen) can be controlled in the combustion process or by adding additional controls. Selective Noncatalytic Reduction (SNCR) is now the most common method for controlling NO_x from waste combustors. With SNCR, ammonia is injected into the combustor's boiler bank above the fire zone. The ammonia reacts with the nitrogen in the combustion gases to form nitrogen dioxide and water. Another method of controlling NO_x is with staged combustion, in which the combustion temperatures are controlled to minimize thermal NO_x generation. Either or both of these options may be appropriate depending on the combustion technology to be used.

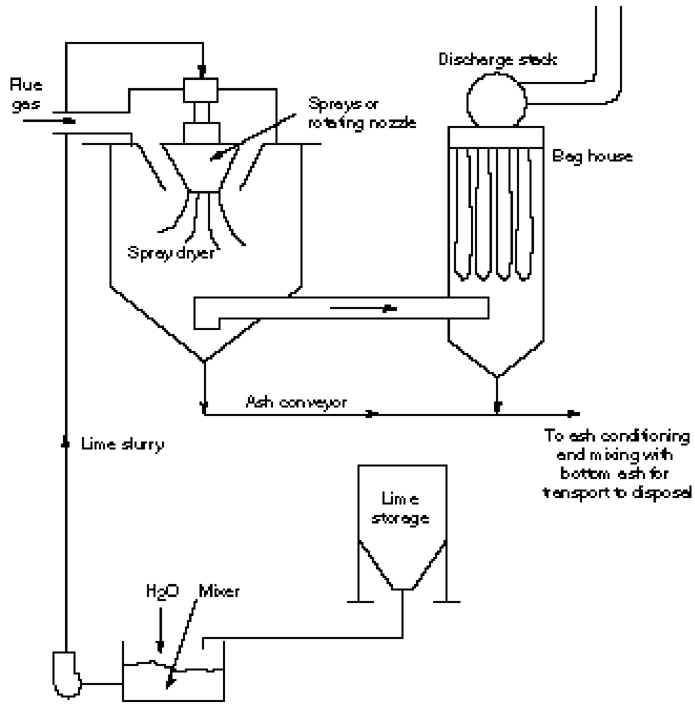
Acid Gas Controls

Acid gas emissions can be controlled by scrubbing acidic gases from the combustor exhaust gas. The products of scrubbing can be recovered either as a dry powder residue or as a liquid. The most common acid gas scrubber technology used in the U.S. is the spray-dry scrubber (Figure 8-10). The flue gas from the combustor is ducted into a reactor vessel, where the incoming flue gas is sprayed with a lime slurry. The lime particles react with the acid gases to form a calcium precipitate. The slurry water cools the incoming combustor exhaust and the water is vaporized; the lime is chemically combined with the chlorides and sulfates and condensed. Lower temperatures are used to promote the chemical reaction with the lime, to promote condensation of most heavy materials in the gas stream, and to control the flue gas temperature in the particulate control device.

Particulate Controls

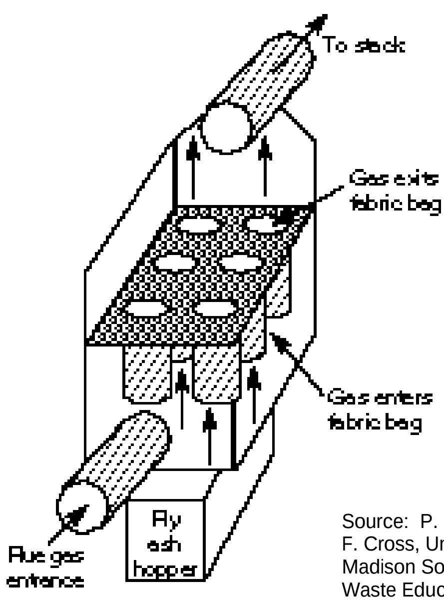
Using fabric filters or baghouses has become the most common method of controlling particulates. Baghouses control particulate emissions by channeling flue gases through a series of tubular fabric filter bags. The bags are set together in an array through which particulates are directed then trapped. Due to the fineness of the fabric mesh and the resulting build up of fine particulates on the bag, the recovered particulates act as an additional medium to further filter out particulates (see Figure 8-11). The collected particulates with the precipitated end products from the scrubber are removed from the bag by various mechanical methods, including reversing the gas flow of cleaned flue gas through the bags by shaking or pulsing the bags.

Figure 8-10
Spray-Dry Scrubber and Baghouse



Source: P. O'Leary, P. Walsh and F. Cross, Univ. of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1987

Figure 8-11
Baghouse Schematic



Source: P. O'Leary, P. Walsh and F. Cross, Univ. of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1987

An inherent advantage of the baghouse systems is that the filtering process also acts as a secondary acid gas scrubber. The collected particles include the unreacted calcium from the scrubber, which also builds up on the bags and will react with any untreated acid gases.

Secondary Volatile Organic and Mercury Control

A developing control technology is the use of activated carbon as an additive to the scrubber process. The carbon is injected into the flue gas before it enters the baghouse to provide additional control of volatile organics and for controlling mercury. Another option is the addition of a carbon filter after the baghouse.

Emission Monitoring

To assist the operator in the proper operation of the combustion process and the emission control equipment, Continuous Emission Monitoring (CEM) equipment has become a requirement for any new or existing waste combustor. CEM systems typically monitor stack emissions of NO_x, carbon monoxide, oxygen, particulate via opacity meters, and acid gases via monitoring sulfur dioxide. Gas temperatures are also monitored to control the scrubber process and to ensure baghouse safety.

ENVIRONMENTAL PERMITTING

Air Permit Regulations

Developing and implementing a WTE facility involves an analysis of the region's air quality, use of the maximum achievable control technology, a detailed projection of the likely emissions from combustion of the waste, and an analysis of the potential impacts those emissions will have on regional air quality, human health and the environment.

Permitting is a complex technical and legal process requiring an experienced, qualified consultant.

Successful facility air permitting requires adhering to new federal and state source emission standards and using the best available control technologies for emission control. Permits are granted on a case-by-case basis through a licensing process, which, in part, involves demonstrating compliance with federal or state standards and showing that plant emissions will cause no significant deterioration of local air quality. It also includes conducting a site-specific health risk assessment. Because permitting and licensing are complex technical processes, it is important to select a qualified, experienced consulting firm to prepare the necessary studies and documents to ensure that the facility is successfully permitted.

Following is a summary of the federal standards and requirements for WTE facilities. The project team must also become familiar with applicable state and local requirements, which may be more stringent than the federal requirements. Federal regulations that will affect the construction and operation of new MSW combustors include the following:

- New Source Performance Standards (NSPS)
- National Ambient Air Quality Standards (NAAQS)
- Prevention of Significant Air Quality Deterioration (PSD) review process for attainment areas
- New Source Review (NSR) for nonattainment areas
- Operating Permit Review and periodic renewal.

New Source Performance Standards (NSPS)

NSPS standards apply to all new WTE units greater than 250 tons/day capacity.

The USEPA established "new source performance standards" for new solid waste combustors on February 11, 1991. These standards apply to all new WTE facilities with individual units greater than 250 tons per day (225 Mg/day) in waste combustion capacity. When establishing the facility's maximum capacity, the regulations assume the municipal solid waste has a higher heating value of 4,500 Btu's per pound. Should the service area's waste stream have a heating value greater than 4,500 Btu's per pound, these standards would apply to a facility that was intended to fire a lesser tonnage. NSPS emission standards for all types of waste combustors is provided in Table 8-6. The metals emission standard is measured as particulate and is equivalent to the particulate emission standard.

In addition, NSPS established carbon monoxide emission limits for each type of combustor. Because of differing operating characteristics, waste combustors will exhibit slightly varying carbon monoxide emissions. Table 8-7 shows minimum standards established for various combustion technologies.

Best Available Technology

The USEPA minimal emission standards are based on the use of SNCR (selective noncatalytic reduction) technology for NO_x control and spray-dry scrubber and a fabric filter for acid gas and particulate control. The NSPS also established "good combustion practices" (GCP) for controlling organic emissions. Although the emission standards are based on the emission control technologies described above, alternative technologies can be used to meet the emissions performance standards.

Operator Certification

Operator training and certification are required.

Another integral part of the NSPS is the American Society of Mechanical Engineers (ASME) Standardized Test Program for the "Qualification and Certification of Resource Recovery Operators." This is a standardized operator testing procedure administered by the ASME. The test verifies that the chief operator and the shift supervisors of WTE facilities are properly trained and, therefore, qualified to operate a municipal waste combustor. In addition, the facility owner or operator must ensure that on-site training is available and reviewed with all employees involved in the operation of the municipal waste combustor.

Co-Fired Facility

Facilities that fire RDF in combination with coal are subject to the NSPS regulations for waste combustors if that facility fires RDF at a rate greater than 30

Table 8-6

NSPS Emission Standards for All Types of Waste Combustors

Particulate	0.015 GR/DSCF @ 7% O_2
SO_2	30 ppmv @ 7 % O_2, or 80% reduction
HCl	25 ppmv @ 7% O_2, or 95 % reduction
NO_x	180 ppmv @ 7% O_2
Dioxin/Furan	30 ng/Nm^3 @ 7% O_2

Source: USEPA

Table 8-7

Minimum Carbon Monoxide Standards for Various Combustion Technologies

Combustion Technique	(CO @ 7% O_2)
Mass-burn (water-wall and refractory)	100 ppmv
Mass-burn (rotary)	100 ppmv
Modular (starved and excess air)	50 ppmv
RDF Stoker	150 ppmv
Fluidized bed	100 ppmv
RDF/coal co-fired	150 ppmv

Source: USEPA

percent on a weight basis. Facilities firing RDF at a rate less than 30 percent by weight are subject to the environmental emission standards for utility or industrial coal combustors.

"Prevention of Significant Deterioration" (PSD) Determination

PSD review and permitting requirements apply to facilities with emissions above those shown in Table 8-8.

Each new facility, depending on its size and the amount of pollutants that may be emitted on an annual basis, is subject to the requirements for the "prevention of significant air quality deterioration" (PSD) process and federal PSD permit requirements. In addition, depending on the status of the state's air quality program, the PSD permitting process may be delegated to the state permitting agency. Some states are not fully delegated to administer the PSD program, in which case the permitting process is administered jointly with the regional USEPA office. Obtaining a PSD permit can be a lengthy process. A variety of environmental and technical experts will be needed to make an accurate analysis of the existing air quality and the potential impacts the proposed facility will have on it and to properly prepare the necessary documentation.

If a facility's projected annual emission rate is greater than the amounts listed in Table 8-8 for any one of the potential pollutants, the facility will be subject to the requirements of a PSD review and permitting process. The PSD process includes the following requirements:

- **Existing Air Quality Analysis:** A detailed analysis of the existing ambient air quality of the area surrounding the facility is necessary. Depending on the availability of existing air quality data and the potential facility emissions and their impact, there may be a need to establish ambient air monitoring sites to collect data for a period of as long as a year prior to submission of the final PSD permit application.
- **Best Available Control Technology (BACT) Analysis:** The PSD application must include an analysis of alternative control technologies that might be used to control facility emissions through a process called "top-down" technology review. All relevant control technologies must be identified by the applicant and each option analyzed for its economic, energy, and environmental costs to determine which option will provide the best control at an acceptable cost. The control technology meeting the specified criteria will then be selected as the facility's BACT. Such a review can require emission limits based on control technologies beyond those for which the NSPS standards are based.
- **Emission Dispersion Modeling:** A detailed analysis of the impact that the facility's emissions are likely to have on the ambient air quality must be performed by modeling the expected emissions using local meteorological data over a five-year period to demonstrate that the proposed

Table 8-8

PSD Significant Emission Rates

Pollutant	Annual Emission (tons per year)
Particulate matter	100.0
Carbon dioxide	100.0
NO_x	100.0
Acid gases (SO_2 and HCl)	40.0
MWC metals (measured as PM)	15.0
MWC organics (measured as dioxins and furans)	3.5 *(10)-6

Source: USEPA

facility will not exceed the ambient air quality standards. Again, if sufficient data is not available, ambient monitoring may be required. The allowable increase (increments) in ambient air quality will vary with the existing air quality and the location of the facility. Allowable increments are given on a first-come, first-served basis, so it is incumbent for the project team to seek and secure those increments on a timely basis.

- **Facility Plans and Specifications:** The PSD permit application requires that the applicant provide general information about the facility to be constructed. Such information includes a facility description outlining the nature, location, design, and typical operating schedule, and including specifications and drawings showing the relevant design and plant layout; a detailed construction schedule; and a detailed description of the emission control technologies to be used and their effectiveness in controlling emissions. The latter are necessary for providing a detailed emissions estimate.
- **Public Comment and Hearings:** A critical part of the PSD process is providing the public with an adequate opportunity to participate in the decision-making process. Such participation can include public notification, public comment periods, and public hearings on the proposed facility and the facility's likely environmental impacts.

New Source Review (NSR) Permit

PSD requirements apply to facilities that are located in nonattainment areas and that have emissions equal to or greater than those listed for PSD review (see Table 8-8).

A "new source review permit" is required for any proposed facility that will be located in a nonattainment area and that will result in an emission increase equal to or greater than those listed for a PSD review. If the proposed facility is located in a nonattainment area for one or more of the regulated pollutants, the facility can be subject to further potential controls. The level of control will depend on the classification of nonattainment (i.e., the greater the level of nonattainment, the more stringent the level of control). The NSR requirements must be met for any pollutant that is not in compliance; for all other regulated pollutants, the PSD requirements would apply. In addition, an NSR applicant must comply with the following two requirements.

Lowest Achievable Emission Rate

To ensure that the facility will not result in a decrease in the region's air quality, the facility must be equipped with emission control technologies that will achieve emission rates that meet either the strictest emission rate achieved in practice by an existing facility or the strictest limitation in the State Implementation Plan.

Offsets

The facility emission rate of nonattainment pollutants needs to be offset by the reduction of that pollutant from an existing source times a factor that is dependent on the severity of the level of nonattainment of that pollutant.

State Implementation Plan (SIP)

The Federal Clean Air Act requires each state to adopt a state implementation plan (SIP) that provides for the implementation, maintenance, and enforcement of primary and secondary National Ambient Air Quality Standards (NAAQS) for each air quality control region of that state (see Table 8-9). State implementation plans are usually a set of state air pollution emission regulations and controls designed to achieve compliance with the NAAQS. SIPs must contain requirements addressing both attainment and nonattainment areas.

Federal Emission Standards

The current National Ambient Air Quality Standards, as written in the 1990 Clean Air Act Amendments, are provided in Table 8-9.

Table 8-9
NATIONAL AMBIENT AIR QUALITY STANDARDS

Pollutant	Primary Standards	Averaging Time	Secondary Standard
Carbon Monoxide	9ppm (10Mg/m^3)	8-hour[a]	None
	35ppm (40Mg/m^3)		
Lead	1.5mg/m^3	Quarterly average	Same as primary
Nitrogen dioxide	0.053 ppm (100 mg/m^3)	Annual (arithmetic mean)	Same as primary
Particulate Matter	50mg/m^3	Annual (arithmetic mean)[b]	Same as primary
(PM_{10})	150mg/m^3	24-hour[c]	
Ozone	0.12 ppm (235 mg/m^3)1-hour[d]	Same as primary	
Sulfur oxides	0.03 ppm (80mg/m^3)	Annual (arithmetic mean)	—-
(SO_2)	0.14 ppm (365mg/m^3)	24-hour[a]	—-
	—-	3-hour[a]	0.5 ppm (1300mg/m^3)

[a] Not to be exceeded more than once per year
[b] The standard is attained when the expected annual arithmetic mean concentration is less than or equal to 50mg/m^3, as determined in accordance with Appendix K.
[c] The standard is attained when the expected number of days per calendar year with a 24-hour average concentration above 150 mg/m^3 is equal to or less than 1, as determined in accordance with Appendix K.
[d] The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is equal to or less than 1, as determined in accordance with Appendix H.
* Note EPA Regulations 40 CFR Part 50

Residual Disposal

Constituents of bottom and fly ash vary, depending on the materials burned.

A WTE facility and its emission control system produce a variety of residues. By far, the largest quantity is bottom ash, the unburned and nonburnable materials discharged from the combustor at the end of the burning cycle.

The process also produces a lighter emission known as fly ash. Fly ash consists of products in particulate form which are produced either as a result of the chemical decomposition of burnable materials or are unburned (or partially burned) materials drawn upward by thermal air currents in the incinerator and trapped in pollution control equipment. Fly ash includes what is technically referred to as air pollution control residues.

Fly ash normally comprises only a small proportion of the total volume of residue from a WTE facility; the quantity ranges from 10 to 20 percent of the total ash. Distribution of bottom and fly ash is largely influenced by the type of combustion unit. Excess air systems produce the most fly ash; controlled air units produce the smallest amounts.

Constituents in both ash and scrubber product vary, depending on the materials burned. In systems burning a homogeneous fuel such as coal, oil, or tires, levels of pollutants in residuals may be relatively constant. Systems burning a more heterogeneous mixture, such as municipal, industrial, or medical waste, may experience wide swings in the chemical composition of residuals.

The major constituents of concern in municipal waste combustion ash are heavy metals, particularly lead, cadmium, and mercury. These metals may impact human health and the environment if improperly handled, stored, transported, disposed of, or reused (for example, using stabilized ash in construction materials such as concrete blocks).

Solid waste is regulated by two major programs under the Resource Conservation and Recovery Act (RCRA). The RCRA Subtitle C program regu-

Hazardous waste standards may apply to ash disposal.

lates the disposal of solid waste that is hazardous, while the RCRA Subtitle D program regulates nonhazardous solid waste. WTE facilities must determine if their ash is a hazardous waste. This is usually done by testing. Ash classified as hazardous must be handled under RCRA Subtitle C regulations as a hazardous waste. Testing and possible hazardous waste treatment / disposal costs must be considered in economic evaluations of municipal waste combustion. Ash not classified as hazardous must be disposed of in accordance with Subtitle D and state regulations. Many states have their own special requirements for managing municipal waste combustion ash. Readers are urged to check with their state environmental program to determine the current regulatory status of municipal waste combustion ash.

Water Discharge

WTE facilities may also require water discharge permits.

While ash is usually the major residue problem at WTE facilities, some plants also generate wastewater. Those considering construction of a WTE facility should anticipate and acquire all permits necessary for wastewater treatment and disposal.

Surface Water Concerns

Wastewater at a WTE facility can be generated in various forms. These include tipping floor runoff system wash water, ash quench water, and water from pollution control systems. These systems also must deal with normal problems experienced by all large industrial facilities, including sanitary wastewater disposal and surface-water runoff. For most WTE facilities, wastewater can be recycled in a closed-loop system. In these systems, water from floor drains, ash dewatering, water softener recharge, and other process wastewaters are collected and stored in a surge tank. This water is then reused for ash quenching. Sanitary waste can be directed to municipal sewer systems.

For most facilities, the quantity of water used amounts to a few gallons per ton of refuse burned. Usually this effluent can be discharged to a local sewer system. In some cases, regulatory authorities may require that the waste stream be pretreated before discharge. State regulatory agencies and local sanitation officials should be consulted to determine the best method of handling wastewater.

Groundwater Concerns

Groundwater contamination at WTE facility sites has proven to be unlikely. Proper management and handling of surface waters and proper ash disposal will minimize potential contamination of groundwaters.

Local and Other Federal Program Requirements

The construction and operation of a WTE facility also requires several other permits, many of which satisfy local requirements, such as those for zoning or traffic. There are, however, two permits that are administered by federal agencies.

Public Utilities Regulatory and Policy Act (PURPA)

Be careful to review and comply with all pertinent regulations.

The Public Utilities Regulatory and Policy Act was established to encourage the development of co-generation facilities to support existing electrical generating capacity. PURPA requires utilities to purchase electricity from producers at the utilities' "avoided cost," that is, the cost of building that capacity or the cost of operating at a higher capacity. The application for certification of added capacity is administered by the Federal Energy Regulatory Commission.

Federal Aviation Administration (FAA)

The FAA controls the height of structures in the flight path of air traffic and the marking of structures that may be of excessive height. The purpose is to ensure that structures (for example, the stack) are not constructed in the direct flight path of any landing strip and that they are properly marked and lighted to warn air traffic of their existence. In some instances, stack height is restricted.

Other Environmental Issues

Land-Retained Pollutants

Land-retained pollutants originating as stack or fugitive emissions are of increasing concern. Bio-accumulation and subsequent ingestion from food is an indirect exposure route resulting from land-retained emissions. To provide better understanding of land-retained pollutants, it may be desirable to establish baseline contaminant levels before plant construction so changes in those levels throughout the plant's operating lifetime can be monitored.

Noise Pollution

Each potential environmental issue must be carefully evaluated.

Truck traffic is the greatest source of noise pollution resulting from WTE plant operations. Well-maintained and responsibly operated trucks will help minimize this problem. Local ordinances may restrict truck traffic to certain hours of the day and to specified truck corridors. Under these conditions, noise pollution should not be a significant factor.

Noise resulting from plant operations and air handling fans associated with the combustion and emissions control equipment is also a potential problem. Noise levels are likely to be highest in front of waste tipping floor doors, ash floor doors, and in the vicinity of the air emissions stacks. Most states have standards for noise levels from industrial facilities of this type. Walls, fences, trees, and landscaped earthen barriers can serve to reduce noise levels.

Aesthetic Impacts

Negative aesthetic impacts can be prevented or minimized by proper site landscaping and building design. Such impacts are much less problematic if the facility is sited in an industrial area and not adjacent to residential or commercial districts. Local zoning ordinances may ensure that aesthetic pollution does not occur. Environmental impact assessments should discuss potential aesthetic effects from a WTE project.

Keeping the process building at negative pressure can prevent undesirable odors from escaping outside of the building. Using air internal to the process building for combustion air in the plant processes will destroy most odors. Visible steam or vapor plumes can be emitted by some facilities. Smoke resulting from improper conditions in the combustion chamber can also be problematic. Air emissions stacks and cooling towers may also be unappealing anomalies in the skyline of some areas. If external lights on buildings prove objectionable to neighbors, perimeter lights on stands directed toward the plant may be preferable.

Land Use Compatibility

Ideally, a WTE plant will be located where it is considered a compatible or nondisruptive land use. Choosing an incompatible site can serve as a catalyst for any existing public opposition to siting a facility. Construction in an industrially zoned area may be considered an example of siting in a compatible land use area.

The availability of undeveloped land around the facility will mitigate any unexpected and undesirable impacts by the facility. Having additional land available is also desirable for future expansion and the installation of additional energy recovery or emission controls as conditions change over the life of the facility.

Environmentally Sensitive Areas

An environmental impact statement should thoroughly document the impacts of WTE operations on environmentally sensitive areas. Contaminant levels of metals and other substances should be established downwind and near the facility to use as a baseline for measuring future impacts on environmentally sensitive areas.

Health Risk Analysis

A health risk assessment may be necessary.

Humans can be exposed to air emissions from WTE incinerators through direct and indirect pathways. The most common direct pathway is inhalation of pollutants; indirect pathways can include ingestion of contaminated food or water. Both direct and indirect pathways through which pollutants enter humans and ecosystems should be documented and accounted for in WTE risk assessments. Land- and water-retained fallout is a growing concern for risk assessments.

Traditionally, risk assessment calculations have focused on air emissions. Potential problems associated with storage, handling, and disposal of ash should also be identified. Risk assessments should provide a full comparison of alternative waste management options and their associated risks.

Role of the Contractor in the Permitting Process

An environmental permit application must be consistent with the performance characteristics of the technology and operations procedures that will be employed. If the applications are not consistent with the performance characteristics, it may be necessary to reapply for some permits if there are technological changes requiring permits. Depending on the negotiated positions taken in the contracting process, either the contractor or the municipality will have a significant role in negotiating the permit language outcome.

Regulatory Approval Summary

Implementing an energy recovery project will require strict compliance with state and local regulations.

Implementing an energy recovery project will require strict compliance with state and local regulations. State permits must be acquired for air and water emissions and solid / hazardous waste disposal. Local governments may require special land-use approval or variances for land use impacts, including nonconforming zoning and overweight loads.

Obtaining permits for waste-to-energy facilities can be controversial, especially when community concerns are not appropriately addressed. Project progress depends upon anticipating these concerns throughout the siting process. Project development can be more effective when information is freely provided to the public during facility siting. The information in Chapter 2 on siting facilities should be carefully reviewed.

SITE SELECTION

As the project team identifies the geographic area to be served, the quality and quantity of solid waste available, and the viable energy markets, they can begin focusing on potential facility sites and identifying the technologies that will be required to meet the needs of specific markets.

The choice of site affects the technology needed.

For example, if one major steam buyer is available who can accept all the energy produced by a facility, a mass-burn facility or an RDF system with a dedicated boiler may be the best alternative. On the other hand, if a variety of industries are present in an area, but are miles apart, an RDF facility to provide these industries with supplemental fuel may be an alternative worth exploring.

However, depending on the local public utility's payment rate for the electricity produced, either a mass-burn or an RDF unit with a dedicated boiler may prove to be the most feasible. The mix of markets that provides the best economic outlook for the developer will provide the basis for choosing the technology that will be used to burn the waste and produce the desired energy.

Map Overlay Technique For Potential Sites

Waste supply, energy market, and land use information can be displayed in several different formats, including overlay maps, manually tabulated summaries, and computer-assembled tables. Mapping helps narrow down potential sites through a process of elimination based on predetermined criteria.

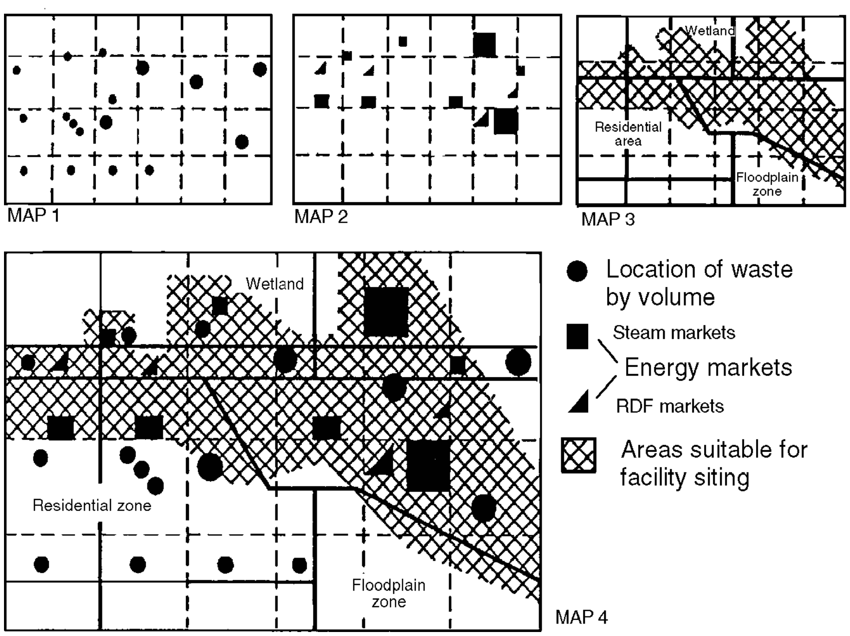
Overlay mapping helps eliminate sites based on predetermined criteria.

The preferred approach is to list all possible customers and the type of energy useful to them. For example, a hospital complex could heat and cool buildings with low-pressure steam; a manufacturing plant could use high-pressure steam; or an electric power plant could burn RDF. Note that selection in advance of a particular technology may limit potential energy customers to some degree.

As energy markets are being identified, an inventory should be conducted of land use in the service area. This will identify potential facility sites. The inventory should take into account highway system characteristics, sensitive environmental settings, land use compatibility, and zoning or regulatory constraints.

Figure 8-12

Waste-to-Energy Facility Siting Map Overlay Example



Source: P. O'Leary, P. Walsh and F. Cross, Univ. of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1987

An example of map overlays is shown in Figure 8-12. Each area's available waste quantity is shown as a solid black circle (see Map #1, Figure 8-12); areas with relatively high waste generation rates have larger circles and the concentration of circles shows where the most waste is generated. In a similar fashion, potential energy customers are identified by squares and triangles representing where and how much steam and RDF may be used (see Map #2, Figure 8-12). The use of primary colors or patterns on transparencies are other options for overlays. Land use compatibility and general environmental conditions are also documented (see Map #3, Figure 8-12). Compatible areas indicated on the map are those that have not been deemed environmentally sensitive; those excluded from consideration in this example are wetlands, floodplains, and residential zones. Major roads are also shown on the map.

When the three maps are overlaid, locations with the service area that may be suitable for a steam or RDF WTE facility become evident (see Map #4, Figure 8-12). Areas where waste supply, energy demand, and suitable land use coincide are good candidates for the construction of either a steam-producing incinerator or an RDF plant and a dedicated or co-fired RDF boiler. The best option will be selected during the detailed evaluation of alternatives.

Detailed Site Evaluation

After the initial site screening process is completed, one or more viable sites may be available. The selection of the final site should be based on a more detailed and comprehensive environmental and technical evaluation. The selection criteria should be based on specific design requirements for the facility, including the following:

Final site selection is based on a comprehensive environmental and technical evaluation.

- adequate land area
- subsoil characteristics to structurally support the facility
- access to water supplies for the process and cooling
- access to required utilities
- access to the energy market.

In addition, each site should be evaluated in detail for its social and environmental compatibility for this type of facility, including the following:

- compatibility with oother land use types in the neighborhood
- evaluation of the area's flora and fauna
- determination of any archaeological sites or protected species existing on the site.

Detailed investigations are conducted at each site. Site access is usually arranged by negotiating an option to purchase with the land owner. If several sites will be considered in detail, this phase of the assessment is usually divided into two parts: First, the available information is used to shorten the list of candidate sites; second, the few remaining sites should be studied in detail.

RESPONSIBILITY FOR FACILITY OPERATION

How and by whom the facility will be managed are crucial questions for the development team.

How the facility should be managed and by whom the facility should be operated — by public employees or by a private contractor — are major decisions for the implementation team. There are several issues to consider. First, it is essential that the facility be effectively managed and operated, and that a properly trained and well-managed team be assembled to operate the facility. Important factors to consider include the availability of qualified personnel, the level of pay that can be offered under the existing municipal compensation structure, and whether the pay structure is competitive enough to attract qualified personnel.

In addition, a WTE facility is an industrial plant that requires both daily and annualized maintenance using specialized services and an administrative staff to procure and manage that service. The municipality's procurement methods and policies under both state and local laws and regulations should be evaluated to determine if those services and replacement components can be procured in a timely manner.

Keeping the facility online is critical to its financial success. In the event of an outage, the operating agency must have the ability and authority required to get the facility back online as quickly as possible. The cost to the service area when a facility is out of service can be great; quick action to re-establish service is essential.

Public Operation

When considering public operation of a WTE facility, a number of factors are important.

In the past, public facilities were operated by public employees. That is no longer the norm with complex facilities like WTE, which require unique skills or talents to effectively maintain and operate. However, there are still many publicly operated WTE facilities. The advantages of a public operation include the ability of the municipality to have full control of the day-to-day operation and to gain all the economic revenue benefits from the operation. The disadvantage is that all of the day-to-day problems, costs, and liabilities are also borne by the municipality.

To make an informed decision to operate a WTE facility, the decision-making body should consider the need for the following:

- attracting and adequately compensating trained and qualified staff members
- procuring emergency outage repair services quickly
- maintaining sufficient budgetary reserves to make unexpected repairs
- accepting financial damages from the energy buyer if the facility is unable to provide power according to the energy sales agreement
- assuring the bond holders that their investment will be well maintained and the facility will operate for the term of the bonds
- availability of qualified experts (i.e., combustion, instrumentation, environmental, etc.) to meet the day-to-day operating demands.

Private Operation

Private operation reduces the community's obligations and responsibilities but also means relinquishing control.

To offset some of the major operating risks of this type of facility, there may be a long-term advantage to using the services of a private operating company to operate and maintain the facility. In this case it is essential that the project team establish a process for selecting a well-qualified and financially secure operating company.

The operating company will probably assume several of the municipality's obligations in operating the plant. Among them will be the requirement to take the city's waste and process it into energy. By contracting with a private company, the municipality will be transferring some of the major operating risks to that company. In turn, the operator will expect to receive compensation in the form of a share of the energy revenues or additional operating fees. The contractor should also be required to pay for any increased costs for failure to provide that service.

The advantage of using a private operator will be offset by the municipality relinquishing some of the day-to-day operating control and decisions in plant operations. However, the municipality will gain financial security because the operator will be obliged to pay for the cost of failing to meet specific contract obligations between the municipality and the energy buyer.

METHOD OF FINANCING

The method of financing selected will affect the subsequent project execution options available and will involve potentially complex contractual and tax issues. Project financing can be a very complex process requiring detailed legal and tax issues that need to be carefully reviewed and understood. After deciding to develop the project, it is to everyone's advantage to seek qualified financial advisors and make them an active part of the project team as soon as

Financing methods affect subsequent project options.

possible. Potential project financing alternatives include the following:

- general obligation (G.O.) bonds
- municipal (project) revenue bonds
- leverage leasing
- private financing.

General Obligation (G.O.) Bonds

The least complex option is general obligation bonds, and, depending on the credit rating of the municipality, it may be the least costly option in interest rates. The bonds are backed by the full faith and credit of the municipality based on its ability to levy taxes as necessary to pay the principal and interest on the bonds. Financing the project by this method may affect the municipal debt capacity for future projects and its credit rating for those projects.

General obligation bonds also allow the municipality full flexibility to use traditional municipal project execution methods and allow public operation of the project. For securing funding, this method also requires the least direct technical or economical analysis of the project's details to be funded. Each of the other financing methods involves more complex project contracting and economic reviews to support the project feasibility and each has implications to the project and municipality that requires an expert analysis to clearly understand the implications under the relevant federal and state tax laws.

Municipal (Project) Revenue Bonds

Project revenue bonds are based on the credit worthiness of the project and the parties involved, the technological feasibility (i.e., is the technology to be used "proven"?), and the project's revenue forecast. The bond holder is not in a position to take project execution risks. Therefore, either the contractor or the municipality must take the financial risk for any deficiencies in the project technology, changes in the project's forecasted income, or other project-related risks.

Leverage Leasing

Leverage leasing is a method of project financing that allows private investment in the project in combination with public debt. Under this method, a private investor becomes the owner of the facility, and the tax benefits of owning the facility will thereby offset the taxes that may be due for profits from the owners of other enterprises. The private equity, typically around 20 percent of the project capital cost, is based on the value of those tax benefits and the rate of return the private investor expects to receive from the investment. The municipality gains the benefit for reducing the public debt necessary to finance the project and the reduced debt service payment from that debt.

With leverage leasing, the municipality does not own the facility and, therefore, "leases" the facility back for the term of the debt service payments. The facility is subject to local property taxes that would be paid to the host community. Once the debt has been fully paid, the facility is owned by the private investors.

Private Financing

Private financing has been used for WTE projects which are developed by a private development group. As in the case of leveraged leasing, the private developers attempt to use some form of tax exempt debt to make the project financially feasible. The municipality would likely be committing to a long-term contract to deliver waste to the facility at a specified tipping fee to financially support the project.

RISK-TAKING POLICY

Constructing and operating a WTE facility requires the participants to carefully consider project execution risks. Many risks can be covered by insurance but without a proper risk management program, the cost of insurance could be considerable or become unavailable as a result of a poor management history. Major risk issues that should be addressed include the following:

The appropriate approach for managing risk must be established.

- availability of waste
- availability of markets and value of energy and recovered materials
- facility site conditions
- cost of money (i.e., bond interest rate)
- compliance with environmental standards (short- and long-term)
- waste residue and disposal site availability
- construction cost and schedule
- operating cost and performance
- strikes during construction and operation
- changes in laws (federal, state, and local)
- long-term environmental impact and health risks
- unforeseen circumstances (force majeure)
- long-term operating costs
- long-term performance.

Clearly, the party with the least control is the bond holder. Therefore, the bond underwriter will accept little if any risk and will monitor the project negotiations and final documents to satisfy itself that the project is viable, both technically and financially. Their review will include the financial and technical viability of all contracting parties.

Private contractors are usually willing to take those risks that they control. Asking a contractor to take risks that are beyond their control, such as availability of waste, may be good short-term politics, but can jeopardize the long-term financial stability of the contractor and the project.

PROCUREMENT APPROACHES

Having made the decision about who will operate the facility, the method of financing and the risk-taking position of the municipality, the project team can select the method of implementation that reflects those decisions.

The Architect/Engineer Approach

The traditional architect / engineer (A / E) approach involves the municipality retaining a qualified firm to design and procure the WTE facility employing procurement methods used traditionally by municipalities for public facilities. Although this has been used for many WTE facilities, this method will involve the greatest risk to the municipality for facility performance and construction cost overruns. In addition, there will be a need to allow for adequate operator participation in the design phase. This approach could be used if the municipality will own and operate the plant. Also, financing would probably be limited to general obligation or revenue bonds backed by that municipality.

The Turnkey Approach

The turnkey approach involves selecting, through competitive bidding or other appropriate competition, a qualified team or company to design, build, and demonstrate the performance of the WTE facility according to predefined performance criteria. Turnkey contractors usually have more freedom in the detailed plant design and construction of the facility to meet the performance specifications.

The Full-Service Approach

Select the approach that best satisfies project objectives

The full-service approach involves selecting a company willing to accept a full service obligation with the municipality to take the municipality's waste and process it to produce energy at an agreed upon energy conversion rate. The full-service company will, for an agreed upon construction and operating price, design, construct, and operate the facility for the term of the project, typically for the term of the bonds.

This option enables the municipality to minimize its risk because the contractor will be accountable for the cost of construction or any schedule delays or cost overruns. It gives the municipality added security by providing the municipality with a known operating fee for the length of the contract. Risks associated with deficiencies in the technology over the length of the contract, labor costs, equipment replacement costs, etc., are all assumed by the contractor. However, because those risks are passed on to the contractor, the contractor will expect and should receive greater freedom to execute its obligations (i.e., the municipality will have less control of day-to-day facility activities that are not specified in the contract). The full-service approach, which is the most common implementation method used today, allows the municipality to finance the project through several instruments, including public and private funding.

CONSTRUCTION AND OPERATION PHASE

Be prepared to address complex issues during facility construction.

Having completed the financing and execution of the project contracts, the community can then begin project execution, which will involve two or more years of construction and twenty or more years of operation.

It is not uncommon to disband the project development team at this time and turn the project over to new individuals or organizations to implement. The method the community chose for executing the project (i.e., public, private, etc.) will dictate the type of organization that will be needed to manage the project. In many cases, the level of staff involvement is underestimated. Many complex issues needing expert input can still come up, including verifying the facility's performance with contract specifications and its compliance with environmental standards. The bond holder may be represented by an independent engineer to certify that the constructed facility conforms with those standards. There may be unanticipated situations requiring some form of dispute resolution.

How these issues are handled and resolved will greatly reflect the project developers' competence in selecting the contractor and negotiating the many contracts required to create the project.

REFERENCES

Boley, G. L. 1991. *Refuse-Derived Fuel (RDF)—Quality Requirements for Firing in Utility, Industrial, or Dedicated Boilers.* International Joint Power Generation Conference, San Diego, CA. October.

EPRI Report. June, 1988. Updated by ABB-RRS, June, 1991.

IWSA (Integrated Waste Services Association). 1993. *The IWSA Municipal Waste Combustion Directory: 1993 Update of U.S. Plants.*

P. O'Leary, P. Walsh and F. Cross. 1987. University of Wisconsin-Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles.

USEPA. 1994. *Characterization of Municipal Solid Waste in the United States: 1994 Update.* EPA530-R-94-042 (November).

USEPA. 1992. *Characterization of Municipal Solid Waste in the United States: 1992 Update.* EPA530-R-92-019 (July).

9

LAND DISPOSAL

The basis of a good solid waste management system is the municipal solid waste (MSW) landfill. MSW landfills provide for the environmentally sound disposal of waste that cannot be reduced, recycled, composted, combusted, or processed in some other manner. A landfill is needed for disposing of residues from recycling, composting, combustion, or other processing facilities and can be used if the alternative facilities break down. The federal government sets minimum national standards applicable to municipal solid waste landfills and these federal regulations are implemented by the states. A properly designed MSW landfill includes provisions for leachate management and the possible collection of landfill gas and its potential use as an energy source. Innovative planning will also facilitate productive use of the landfill property after closure. Good design and operation will also limit the effort and cost necessary for maintaining the landfill after final site closure.

This chapter provides an information base from which to work when designing new landfills and operating existing facilities. It also provides information necessary for closing an entire landfill, closing completed phases of an operating facility, and for providing long-term care at a closed landfill.

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9 ❖ HIGHLIGHTS

Modern MSW landfills:
- provide for disposal
- produce usable gas
- can provide useful land after closure.

(p. 9-9)

MSW landfills provide for the environmentally sound disposal of waste that cannot be reduced, recycled, composted, incinerated, or processed in some other manner. A landfill is needed for disposing of residues from recycling, composting, incineration, or other processing facilities and can be used if the alternative facilities break down. A properly designed MSW landfill includes provisions for collecting landfill gas and for its potential use as an energy source. Innovative planning may also facilitate productive use of the landfill property after the landfill is closed.

Building a landfill requires large sums of money and long periods of time.

(p. 9-11)

Careful planning by the developers of new or expanding landfills is important. A large amount of money and a long period of time are required to build a landfill. Some of the cost elements and time periods are listed below:

- siting, design, and construction: 3-10 years
- operation, monitoring, and administration: 15-30 years
- closure: 1-2 years
- monitoring and post-closure maintenance: 30 or more years
- remedial actions: unknown.

Landfill development can be organized into four phases. A 16-step process is provided in the text.

(p. 9-11)

Landfill development involves numerous technical details, significant public involvement, and extensive regulations. A 16-step process is outlined on page 9-11. The steps are organized into four phases:

- Phase 1 (steps 1-6) involves developing an information base and making some preliminary site decisions.
- Phase 2 (steps 7-12) includes making a detailed design for the landfill and for managing related issues such as groundwater monitoring and leachate and gas management.
- Phase 3 (steps 13-14) involves establishing financial assurance and beginning actual operation.
- Phase 4 (steps 15-16) includes closure and post-closure care.

Determining landfill volume is the first task in the design process.

(p. 9-12 — 9-14)

Estimating landfill volume is the first task in the design process because volume estimates are necessary for determining the landfill's dimensions. The following factors are crucial:

- Determine accurate tonnage estimates of waste to be received at the site. (Chapter 3 provides waste inventory projection procedures.)
- Estimate anticipated increases or decreases in the diversion of material to waste-to-energy facilities, composting, recycling, reuse efforts, or waste minimization efforts.
- Determine density figures for the waste. See Table 9-1 and Table 9-2.
- Estimate the amount of waste settlement.

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Site selection should include consideration of these characteristics.

(p. 9-15 — 9-16)

Potential sites must be in areas that are suitable for landfill development. The following considerations should be key factors in locating and operating a landfill.

- A landfill must be consistent with the overall land-use planning in the area.
- The site must be accessible from major roadways or thoroughfares.
- The site should have adequate quantity of earth cover material that is easily handled and compacted.
- The site must be chosen with regard for the sensitivities of the community's residents.
- The site must be located in an area where the landfill's operation will not detrimentally affect environmentally sensitive resources.
- The site should be large enough to accommodate the community's wastes for a reasonable time (10 to 30 years).
- The site chosen should facilitate developing a landfill that will satisfy budgetary constraints, including site development, operation for many years, closure, post-closure care, and possible remediation costs.
- Operating plans must include provisions for coordinating with recycling and resource recovery projects.

Federal restrictions affecting landfill siting must be considered.

(p. 9-16)

In addition to determining the suitability of a site, location restrictions must be considered. Resource Conservation and Recovery Act (RCRA) Subtitle D requirements place restrictions on locating landfills in the vicinity of airports, in floodplains, wetlands, fault areas, seismic impact zones, and unstable areas. Other federal agencies have standards that also affect landfill siting.

Determine applicable federal, state and local requirements.

(p. 9-18)

The Subtitle D regulations establish national minimum standards for landfills that receive household waste. The states are to incorporate these national minimum standards into their permitting standards, and the state is responsible for permitting, enforcement, etc. Under the authority of RCRA, the USEPA regulates MSW landfilling with regard to the following:

- ground water quality protection
- landfill gas control
- air pollution control
- basic operating procedures
- safety issues
- flood plains
- seismic and slope stability
- disturbance of endangered species
- surface-water discharges
- site closure and long-term care
- closure and long-term care financial assurance.

9 ❖ HIGHLIGHTS (continued)

State and local requirements will also apply.
(p. 9-18 — 9-19)

State regulations vary widely, but usually landfill engineering plans are submitted to the appropriate state-level regulatory body for review and approval. State standards usually contain more detail than Subtitle D standards and address concerns specific to a particular geographic region. State or local governments may require:

- a solid waste landfill plan approval
- a conditional-use zoning permit
- a highway department permit (for entrances on public roads and increased traffic)
- a construction permit (for landfill site preparation)
- a solid waste facilities permit
- a water discharge/water quality control permit
- an operation permit (for on-going landfill operations)
- a mining permit for excavations
- building permits (to construct buildings on the landfill site)
- a fugitive dust permit
- an air emission permit
- a closure permit.

Options for energy recovery must be considered.
(p. 9-19 — 9-20)

Energy recovery from the landfil in the form of landfill gas should be considered. The three uses for landfill gas include (1) as a boiler fuel, (2) as fuel for engine-generators for producing electricity, and (3) as a natural gas supplement.

The final site use must be considered early in the design phase.
(p. 9-20 — 9-21)

The final use of the landfill site should be considered during the initial site decision phase to provide for its best use. Good planning early will minimize costs and maximize the site's usefulness. Planning is particularly important if future construction or building on or near the landfill site is anticipated. Below are potential uses for closed MSW landfills:

- nature or recreation park
- wilderness area or animal refuge
- golf course
- ski or toboggan hill
- parking lot.

Detailed site characterizations are made for the most desirable sites.
(p. 9-21 — 9-25)

A detailed investigation of potential sites must be made by conducting site characterization studies. Thorough site characterizations are conducted in two phases: (1) involves collecting and reviewing as much information as possible about the site, (2) involves field investigations. Most new data collected will concern the geology and hydrogeology of potential sites and will help determine aquifer depths, geologic formations, drainage patterns, depth to groundwater, groundwater flow direction, groundwater quality, and construction characteristics of on-site soils. In addition, data about existing land use, surrounding land development, available utilities, highway access, political jurisdiction, and land cost are tabulated.

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The landfill design process should follow a logical sequence.
(p. 9-26 — 9-27)

Each landfill design project presents a unique combination of timing, site restrictions, waste characteristics, and regulatory and political factors. Some points must be covered and it is helpful to have an initial outline of a logical sequence of activities to follow. Such an outline is summarized in Table 9-3.

Both engineering design standards and performance standards must be met.
(p. 9-26 — 9-28)

Two types of federal, state, and local government standards must be met: (1) Engineering design standards are building codes describing how the facility must be built. Regulating bodies monitor compliance with these standards by reviewing the building plans and inspecting the landfill during construction. (2) Performance standards apply for the facility's life and specify that a certain level of environmental control be achieved and maintained. If the landfill as initially designed does not achieve compliance, operators must install additional protective systems.

Public involvement is crucial to the design process.
(p. 9-28)

Many of the permits needed before landfill design and operating plans are approved require a public hearing for soliciting input from interested parties. The landfill designers should also solicit input from individuals and groups who will be directly affected by the future landfill. Public participation should begin far in advance of public hearings.

State approvals are also required.
(p. 9-29)

Most states employ a multistage approval process similar to the following:

- Required landfill siting regulatory review procedures are initiated.
- A feasibility (engineering) report is submitted to the state for approval.
- Detailed engineering plans are submitted to the state.
- A final application for state landfill operating permits is submitted.

Landfill layout and design is strongly affected by site geology.
(p. 9-29 — 9-31)

Landfill layout is strongly influenced by the site's geology. The potential for gas and leachate migration and the suitability of the soil for landfill base and cover material are crucial. Site layout begins with geotechnical information, including data on the geology, hydrology, and soils at and around the site. These data are usually collected during the site-selection process, then supplemented during site investigations.

Operating plans must include working face configurations and phase dimensions.
(p. 9-31 — 9-32)

The operating plan should describe, in detail, the configuration of the working face of the landfill. Figure 9-7 illustrates a typical cross section of a portion of a municipal landfill, including the "working face," and helps to define terms. The plan should also illustrate the chronological order in which the features are to be developed. In a well-planned phased development, the landfill's end use can begin on completed sections while other areas in the landfill are still being used for disposal.

Leachate variability and concentrations must be considered.
(p. 9-33 — 9-34)

Leachate is a liquid that has passed through or emerged from landfill waste. It contains soluble, suspended, or miscible materials removed from the waste. Table 9-4 shows changes in leachate composition as a landfill proceeds through various decomposition phases. It is imperative when designing leachate collection and treatment facilities to consider the concentrations and variability of leachate with regard to its many constituents. Leachate generation rates depend on the amount of liquid originally in the waste (primary leachate) and the quantity of precipitation that enters the landfill through the cover or falls directly on the waste (secondary leachate).

9 ❖ HIGHLIGHTS (continued)

Predicting leachate amounts is crucial. (p. 9-34 — 9-35)	Several factors influence leachate generation at landfills: climate, topography, landfill cover, vegetation, type of wastes. The amount of leachate generated affects (1) operating costs if leachate collection and treatment are provided, (2) the potential for liner leakage and the potential for groundwater contamination, and (3) the cost of post-closure care. Predicting leachate formation requires water-balance calculations, which can be derived from the water-balance equation provided in Figure 9-10. The equation estimates the amount of precipitation likely to percolate through the landfill cover.
Federal regulatory controls for leachate management must be met. (p. 9-36 — 9-38)	RCRA Subtitle D regulations require that new MSW landfills be designed to control contaminant migration. The groundwater protection performance standard for landfills specifies that contaminant concentrations in groundwater cannot exceed the amounts shown in Table 9-7. Approved states may establish state-specific protocols for meeting these standards.
Composite liners are required at new landfills and expansions of existing landfills, unless an approved state issues alternative standards. (p. 9-38 — 9-41)	A liner is a hydraulic barrier that prevents or greatly restricts migration of liquids, thus allowing leachate to be removed from the unit by a leachate control system. The RCRA Subtitle D MSW landfill regulations require that new MSW landfills and expansions of existing MSW landfill facilities be constructed with a composite liner and a leachate collection system or meet a groundwater protection performance standard. The required liner consists of a flexible membrane placed over a clay layer, forming one composite liner. Figure 9-11 illustrates liner configurations.
Groundwater monitoring systems are required for new and existing units and for expansions. (p. 9-41 — 9-43)	In most cases, groundwater monitoring systems are required for new, existing, and lateral expansions of existing landfills to determine groundwater quality and detect releases of contaminants. New landfills must have such systems installed before wastes are placed in the landfill. The schedule for installing a groundwater monitoring system at existing facilities depends on the location of the landfill with respect to a drinking water source or other state priorities.
Groundwater monitoring begins with detection monitoring. (p. 9-41 — 9-44)	The RCRA Subtitle D groundwater monitoring and corrective action requirements have three steps: detection monitoring, assessment monitoring, and corrective action. Figure 9-14 shows a leaking landfill and one possible type of corrective action. Facilities move through the three steps if a "statistically significant" increase in contaminants is found.
Landfill gas migration must be controlled. (p. 9-43 — 9-45)	Uncontrolled landfill gas migration can be a problem at MSW landfills and must be controlled to avoid explosions in structures in the vicinity of the landfill. Allowable landfill gas concentrations in structures and at the property line are established. Table 9-9 provides typical landfill gas composition.
Controlling gas movement is essential. (p. 9-45 — 9-48)	Controlling gas movement begins with studying the local soils, geology, and nearby area. Gas probes (see Figure 9-16) are used to detect the location and movement of methane gas in and around a landfill. Federal rules require quarterly monitoring.

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Gas can sometimes be recovered for energy.
(p. 9-48 — 9-49)

At some landfills, it is cost-effective to install gas recovery wells or trenches throughout the landfill and recover the gas for its energy value.   Before constructing an energy recovery system, it is important to conduct tests to predict the quantity and quality of gas available.

Final covers for closed landfills must meet federal or corresponding state requirements.
(p. 9-49 — 9-51)

To close an MSW Landfill, RCRA Subtitle D requires that the final cover system be composed of an infiltration layer a minimum of 18 inches thick, overlain by an erosion layer a minimum of 6 inches thick (see Figure 9-20, drawing A).   Landfills with liners must have covers that are at least as impermeable as the liner. Design criteria for a final cover system should be selected to do the following:

- minimize infiltration of precipitation into the waste
- promote good surface drainage
- resist erosion
- prevent slope failure
- restrict landfill gas migration or enhance recovery
- separate waste from vectors (animals and insects)
- improve aesthetics
- minimize long-term maintenance
- otherwise protect human health and the environment.

Other design elements must be considered.
(p. 9-51 — 9-52)

In addition to the major issues of gas and leachate control and final cover, many other elements of landfill design require attention. These include roads, storm water drainage, utilities for landfill operation, and scales for weighing incoming loads of waste.

Obtaining regulatory approval is a long-term process.
(p. 9-52 — 9-53)

Achieving regulatory approval is a long-term effort beginning early in the development process. Chapter 1, on public education, and Chapter 2, on siting, should be consulted for facilitating public participation. Projects lacking public review or input until the design is completed may face substantial delays. Obtaining approval from regulatory agencies is the final task in developing the plan. Close liaison with regulatory people throughout the design process should be maintained to ensure compliance with regulatory standards.

A program for detecting and excluding hazardous and PCB wastes is required.
(p. 9-53)

The owner or operator is required to implement a program to detect and exclude regulated hazardous wastes and PCBs from disposal in the landfill. It should include:

- performing random inspections of incoming loads or other prevention methods
- maintaining inspection records
- training facility personnel
- notifying appropriate authorities if hazardous or PCB wastes are detected.

9 ❖ HIGHLIGHTS (continued)

Select landfill equipment carefully. (p. 9-56 — 9-58)	Equipment at sanitary landfills falls into three functional categories: waste movement and compaction, earth cover transport and compaction, and support functions. The amount of waste is the major variable influencing the selection of an appropriate-size machine. Table 9-12 shows equipment needs.
Safety concerns are crucial. (p. 9-60 — 9-61)	Safety concerns are crucial. To maintain an efficient landfill operation, employees must be carefully selected, trained, and supervised. Safety guidelines specific to the operation of landfill equipment are shown in Table 9-13.
Financial assurance is required. (p. 9-61 — 9-62)	Federal standards require that landfill owners and operators, including municipalities that operate landfills, have financial assurances in place to cover the costs of closure and post-closure. Financial assurance is also required when corrective action is necessary to clean up releases of hazardous constituents to groundwater.
Landfill closure must follow certain procedures. (p. 9-62 — 9-64)	The primary objectives of landfill closure are to establish low-maintenance cover systems and to design a final cover that minimizes the infiltration of precipitation into the waste. Table 9-14 shows the procedures to follow when either the entire landfill or a phase of it has been filled to capacity.

9 LAND DISPOSAL

LANDFILLING—AN OVERVIEW

MSW landfills provide for the environmentally sound disposal of waste that cannot be otherwise managed.

The basis of a good solid waste management system is the municipal solid waste (MSW) landfill. MSW landfills provide for the environmentally sound disposal of waste that cannot be reduced, recycled, composted, combusted, or processed in some other manner. A landfill is needed for disposing of residues from recycling, composting, combustion, or other processing facilities and can be used if the alternative facilities break down. A properly designed MSW landfill includes provisions for leachate management and the possible collection of landfill gas and its potential use as an energy source. Innovative planning may also facilitate productive use of the landfill property after the landfill is closed.

Modern MSW landfills differ greatly from simple land disposal. Today's MSW landfills which have evolved in design and operating procedures over the last 20 years, are very different from landfills of even 5 or 10 years ago. Design improvements have reduced environmental impacts and improved the efficient use of resources.

A schematic of a typical MSW landfill is shown in Figure 9-1. Note that in the completed landfill, the waste is enclosed by cover material at the top and by a liner system at the bottom. Appropriate systems are in place to control contaminated water and gas emissions and reduce adverse impacts on the environment. Key terms used in MSW landfill design include the following:

- **Waste management boundary:** The waste management unit boundary is the boundary around the area occupied by the waste in a landfill. It is measured in square meters or in acres.
- **Liner:** The liner is a system of clay layers and / or geosynthetic membranes used to collect leachate and reduce or prevent contaminant flow to groundwater.
- **Cover:** A typical MSW landfill has two forms of cover consisting of soil and geosynthetic materials: (1) a daily cover placed over the waste at the close of each day's operations and (2) a final cover, or cap, which is the material placed over the completed landfill to control infiltration of water, gas emission to the atmosphere, and erosion. It also protects the waste from long-term contact with the environment.
- **Leachate:** Leachate is a liquid that has passed through or emerged from solid waste and contains soluble, suspended, or miscible materials removed from such waste. Leachate typically flows downward in the landfill but may also flow laterally and escape through the side of the landfill.
- **Leachate collection system:** Pipes are placed at the low areas of the liner to collect leachate for storage and eventual treatment and discharge. Leachate flow over the liner to the pipes is facilitated by placing a drainage blanket of soil or plastic netting over the liner. An alternative

to collection pipes is a special configuration of geosynthetic materials that will hydraulically transmit leachate to collection points for removal.

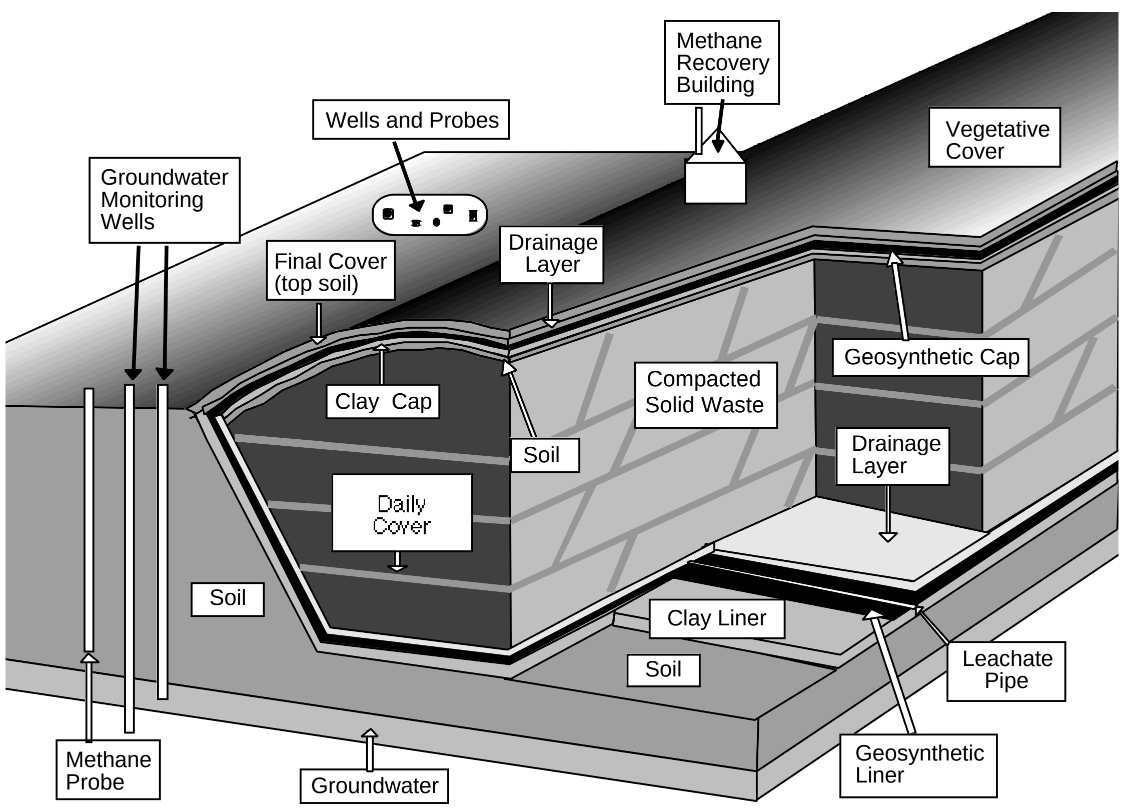
- **Landfill gas:** Generated by the anaerobic decomposition of the organic wastes, landfill gas is a mixture of methane and carbon dioxide, plus trace gas constituents.
- **Gas control and recovery system:** A series of vertical wells or horizontal trenches containing permeable materials and perforated piping is placed in the landfill to collect gas for treatment or productive use as an energy source.
- **Gas monitoring probe system:** Probes placed in the soil surrounding the landfill above the groundwater table to detect any gas migrating from the landfill.
- **Groundwater monitoring well system:** Wells placed at an appropriate location and depth for taking water samples that are representative of groundwater quality.

Owners and operators must carefully plan new facilities and optimize the performance of existing facilities.

The goal of MSW landfilling is to place residuals in the land according to a coordinated plan designed to minimize environmental impacts, maximize benefits, and keep the resource and financial cost as low as possible. To achieve these ends, the solid waste manager and the landfill owner and operator must carefully plan the development of new facilities and optimize the performance of existing facilities.

Figure 9-1

Schematic of a Typical Municipal Solid Waste Landfill



Source: P. O'Leary and P. Walsh, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* 1991-1992

NEW LANDFILLS

Careful planning by the developers of new or expanding landfills is important. A large amount of money and a long period of time are required to build a landfill. Some of the cost elements and time periods are listed below:

- siting, design, and construction: 3-10 years
- operation, monitoring, and administration: 15-30 years
- closure: 1-2 years
- monitoring and post-closure maintenance: 30 or more years
- remedial actions: unknown.

Technical details, public involvement, and regulations make landfill development challenging.

Numerous technical details, significant public involvement, and extensive regulations all present challenges to the new landfill developer. The steps outlined below should be considered:

The steps outlined here provide a helpful structure to guide the process.

1. Estimating landfill volume requirements.
2. Investigating and selecting potential sites.
3. Determining applicable federal, state, and local requirements.
4. Assessing landfill options for energy and materials recovery.
5. Considering the site's final use.
6. Determining the suitability of sites.
7. Designing the fill area to satisfy plan / permit requirements.
8. Establishing a leachate management plan.
9. Instituting groundwater monitoring.
10. Setting up a gas management plan.
11. Preparing landfill final cover specifications.
12. Obtaining plan and permit approvals.
14. Establishing financial assurance for closure and post-closure care.
13. Operating the landfill.
15. Closing the landfill.
16. Providing post-closure care.

These steps may be organized into four phases. The first phase (steps 1-6) involves developing an information base and making some preliminary site decisions. The second phase (steps 7-12) includes making a detailed design for the landfill and for managing related issues such as groundwater monitoring and leachate and gas management. In the third phase (steps 13-14) financial assurance is established and actual operation begins. The fourth phase (steps 15-16) includes closure and post-closure care.

Some of the steps, particularly the design activities in phase two, may take place simultaneously, but it is useful to separate them for discussion purposes. Likewise, many are interrelated; for example, decisions about landfill type will affect plans for leachate and gas control. This chapter discusses each of these 16 steps in detail.

EXISTING OR CLOSED LANDFILLS

Owners and operators of existing landfills must also execute a number of these steps in order to comply with recently established regulations. Leachate and gas management, groundwater monitoring, financial assurance, operating procedures, and closure activities are among the activities described in this chapter which must be carried out at existing landfills. The steps summarized below are equally crucial to existing and closed landfills as they are to new landfills.

The 9 steps summarized here are equally crucial for both existing and closed landfills as well as new units.

1. Establishing a leachate management plan.
2. Instituting groundwater monitoring.
3. Setting up a gas management plan.
4. Preparing landfill final cover specifications.
5. Obtaining closure plan approval.
6. Establishing financial assurance for closure and post-closure care.
7. Operating the landfill.
8. Closing the landfill.
9. Providing post-closure care.

DEVELOPING AN INFORMATION BASE AND MAKING INITIAL SITE DECISIONS

The specific approach followed in designing an MSW landfill will vary from project to project, but certain preliminary information must be gathered and initial site decisions must be made for any project. Landfill volume is the first consideration to be made in the design process. Initial investigations should focus on locating potential sites, determining the applicability of federal, state and local requirements, and identifying the environmental impacts of the landfill. The end use of the site should also be considered during the initial site decision phase. The landfill could be closed with restricted access, or it may be feasible to design systems for productive site end use and energy and materials recovery. These initial design considerations must be addressed before a more detailed design can be developed. This section discusses each of these beginning steps in detail.

Estimate Landfill Volume Requirements

Landfill volume estimates are necessary to determine the dimensions for the landfill. An adequate prediction of landfill volume requirements can be made by projecting records of past landfill volume consumption, refuse weight, or gate volume. Such projections must be made in light of population growth estimates and anticipated changes in commercial or industrial wastes. Depending on the accuracy of previous records, especially with regard to the volume filled per year over the period of record, such a projection can be reasonably reliable and can be used to estimate the landfill volume requirements for a design period of perhaps seven to ten years of site operation.

Accurate tonnage estimates of waste to be received at the site are necessary.

Accurate tonnage estimates of waste to be received at the site will be necessary. Such estimates can range in complexity from simple projections using national or regional data to detailed weighing programs and sophisticated population projections. Chapter 3 provides waste inventory projection procedures.

Once general projections have been made for the amount of waste to be landfilled, the next step is to estimate any anticipated increase or decrease in the diversion of material to waste-to-energy facilities, composting, recycling, reuse efforts, or waste minimization efforts. Other chapters in this guidebook deal with the amount of waste that can potentially be diverted from the landfill by these different options and the amount of materials the landfill can expect to get back from them as residuals requiring disposal. Reusable items such as clothes, doors, windows, appliances, and miscellaneous household items can be separated at the gate and sold. Waste-to-energy plants typically reduce incoming volume by 90 percent and weight by 75-80 percent.

To estimate landfill capacity, one needs density figures for the waste. Density figures at the level of compaction obtained in the typical collection vehicle have been established and are listed in Table 9-1. If the composition of the waste is known, it can be used to estimate the density in the truck, and compaction figures can be used to estimate the density to be expected in the landfill.

The density of material in an MSW landfill depends on refuse composition, moisture content, and the degree of compaction.

The density of material in an MSW landfill is usually 1,000 pounds/cubic yard, but the range depends on refuse composition, moisture content, and the degree of compaction. Table 9-2 lists estimates of the density of several categories of waste as compacted in a landfill. The compacted range is from 185 to 2,800 pounds of refuse per cubic yard of landfill volume. Deeper landfills achieve higher density because the weight of the refuse compacts lower portions of the landfill. When waste is dumped from trucks at the landfill face, it loses its compaction. The load is then broken up as it is spread by the bulldozer and then recompacted by the bulldozer/compactor. Only small-volume landfills with inadequate equipment obtain the lower compaction figure cited.

The amount of soil necessary for daily and final cover must be added to the refuse volume data to obtain the final landfill space projection. The refuse-to-soil ratio usually ranges from 2:1 to 5:1 on a volumetric basis. Therefore, every two to five parts by volume of refuse will require one part by volume of cover soil for all of the various forms of cover in the typical landfill space.

In general, a ratio of 3:1 (refuse to soil) can be used to plan for the operation of most sites. The ratio can be modified upward or downward, depending on any special cover requirements, phasing requirements, or final cover requirements. These figures do not include soil requirements for special berms or unusual amounts of final cover.

A final factor to consider in developing volume estimates is the amount of settlement that will take place. Settlement will occur as the refuse decom-

Table 9-1

Typical Densities of Solid Wastes

Waste	Density Range (lb/cu yd)		
	From	To	Typical
Residential (uncompacted)			
Food Wastes (mixed)	220	810	490
Paper	70	220	150
Cardboard	70	135	85
Plastics	70	220	110
Glass	270	810	330
Tin cans	85	270	150
Aluminum	110	405	270
Leaves (loose and dry)	50	250	100
Yard trimmings	100	380	170
Green grass (loose and moist)	350	500	400
Green grass (wet and compacted)	1000	1400	1000
Municipal Waste			
In compactor truck	300	760	500
In landfill			
normally compacted	610	840	760
well compacted	995	1250	1010
Commercial Waste			
Food wastes	800	1600	910
Wooden crates	185	270	185
Construction and Demolition Waste			
Mixed demolition (noncombustible)	1685	2695	2395
Mixed demolition (combustible)	550	675	605
Mixed construction (combustible)	305	605	440
Broken concrete	2020	3035	2595

Source: Tchobanoglous et al. *Integrated Solid Waste Management: Engineering Principles and Management Issues,* 1993

Table 9-2
Summary of Density Factors for Landfilled Materials

Material	Density (lbs/cu yd)
Durable Goods*	475
Nondurable Goods	
Nondurable paper	800
Nondurable plastic	315
Disposable diapers	
Diaper materials	795
Urine and feces	1,350
Rubber	345
Textiles	435
Misc. nondurables (mostly plastics)	390
Packaging	
Glass containers	
Beer & soft drink bottles	2,800
Other containers	2,800
Steel containers	
Beer & soft drink cans	560
Food cans	560
Other packaging	560
Aluminum	
Beer & soft drink cans	250
Other packaging	550
Paper and Paperboard	
Corrugated	750
Other paperboard	820
Paper packaging	740
Plastics	
Film	670
Rigid containers	355
Other packaging	185
Wood packaging	800
Other miscellaneous packaging	1,015
Food Wastes	2,000
Yard Trimmings	1,500

* No measurements were taken for durable goods or plastic coatings.

Source: USEPA, *Characterization of Municipal Solid Waste in the United States: 1994 Update*

The surface will settle to 80 or 85 percent of the original (undecomposed) height within five years.

poses or becomes compacted by the weight of overlying materials. For average-to-good compaction (1200 pounds per cubic yard), the surface will settle to 80 or 85 percent of the original (undecomposed) height within five years. This probably will be 90 percent of the ultimate settlement. Some landfills have soil temporarily placed on the surface, the weight of which will promote settlement to final grades.

Conduct Initial Investigation and Select Potential Sites

Landfill site selection is usually an extensive process which will likely involve public input. More information regarding facility siting is provided in Chapter 3.

Starting the Project

Clearly identifying project objectives and having well-defined goals and objectives are important.

The community or private company developing a landfill should clearly identify project objectives; having well-defined goals and objectives makes it easier to communicate with citizens (those who support and those who oppose the project) and with political officials. Each party involved will have specific needs to address, but common factors will include the following:

- geographic area and population to be served by the site
- type of waste and quantity to be disposed of
- tipping fee or cost of operation
- unacceptable wastes
- maximum hauling distance
- minimum, and possibly maximum, site operating life span
- profile of potential site users.

Developers must determine if the new facility can compete economically with existing facilities.

If the addition of a new facility means that more than one landfill or waste recycling / treatment operation will be serving the area, facility developers must determine if the new facility can compete economically with existing units. For example, there are recent indications that economies-of-scale favor large landfill sites. When planning to develop such a site, however, one must compare the cost of hauling longer distances to the large landfill with the economics of existing waste management options.

Fulfilling Land Use Goals

Potential sites must be in areas that are suitable for landfill development. Operation and end use of a landfill site should also conform to long-term land use goals. Most areas have projected land-use plans of 10 to 20 years.

Special consideration must be given when evaluating potential sites in areas with endangered plant or animal habitats, virgin timber land, wildlife corridors, unique physical features, or significant historical or archaeological sites. Developers should anticipate possible competing land use interests associated with such areas and realize that certain aspects of the siting and development process may be more complicated. A careful evaluation of possible short- and long-term environmental, political, and social impacts should be made and the anticipated benefits of developing the site must be evaluated in light of the potential impacts and the availability of alternative sites.

Potential sites should be in areas where a landfill will conform with long-term land use goals.

A site selected for a landfill will have some characteristics that are less than ideal. Engineering techniques may overcome these limitations and enable the site to meet design goals, but it is important to start with the best site possible. In selecting a site, some factors to consider include health, safety, accessibility, drainage, soils, proximity to groundwater and surface water, zoning, hauling distance, and adjacent land use. The following considerations should be key factors in locating and operating a landfill.

- A landfill must be consistent with the overall land-use planning in the area.
- The site must be accessible from major roadways or thoroughfares.
- The site should have an adequate quantity of earth cover material that is easily handled and compacted.
- The site must be chosen with regard for the sensitivities of the community's residents.
- The site must be located in an area where the landfill's operation will not detrimentally affect environmentally sensitive resources.
- The site should be large enough to accommodate the community's wastes for a reasonable time (10 to 30 years).

- The site chosen should facilitate developing a landfill that will satisfy budgetary constraints, including site development, operation for many years, closure, post-closure care, and possible remediation costs.
- Operating plans must include provisions for coordinating with recycling and resource recovery projects.

Federal, state, and local regulations for landfill siting must be followed.

In addition to determining the suitability of a site, location restrictions must be considered. Resource Conservation and Recovery Act (RCRA) Subtitle D requirements place restrictions on locating landfills in the vicinity of airports, in flood plains, wetlands, fault areas, seismic impact zones, and unstable areas. RCRA Subtitle D location restrictions include the following:

- **Airports:** If a landfill is located within a specified distance of an airport, the owner or operator must demonstrate that the landfill will not present a bird hazard to aircraft.
- **Flood plains:** For landfills located on a 100-year flood plain, the owner or operator must demonstrate that the landfill will not restrict the flow of a 100-year flood, reduce the storage capacity of the flood plain, or result in the washout of solid waste.
- **Wetlands:** New landfills and lateral expansions cannot be located in wetlands except where an owner demonstrates to an approved state/tribe that there is no practical alternative. The landfill must not cause or contribute to violations of any state water quality criteria, contribute to significant degradation of wetlands, cause net loss of wetlands, or violate any other federal requirements.
- **Fault areas:** New landfills and lateral expansions must not be located within 200 feet of a fault that has experienced displacement during the Holocene Epoch (approximately the last 10,000 years) unless it can be shown to an approved state/tribe that damage to the unit can be prevented at shorter distances.
- **Seismic zones:** New landfills and lateral expansions are restricted in areas susceptible to ground motion resulting from earthquakes. If the site is in an earthquake zone, investigations that demonstrate to an approved state/tribe the suitability of locating a landfill at the designated location must be conducted.
- **Unstable areas:** Unless it can be demonstrated otherwise, landfills must not be located in areas susceptible to natural or human-induced events or forces capable of impairing the integrity of landfill components. Examples of unstable areas are those with poor foundation conditions, areas susceptible to mass movements (landslides, rock falls, etc.), and areas with karst terrains (sinkholes).

In addition to USEPA, other federal agencies have established standards that affect the identification of potential sites.

Other federal agencies have established standards that will also affect the identification of potential sites. For example, Federal Aviation Administration Order 5200.5 establishes a zone within which landfill design and operational features must be used to prevent bird hazards to aircraft. Owners or operators proposing to locate a new landfill or a lateral expansion within a five-mile radius of a public-use airport must notify the affected airport and the FAA.

Using Soil Maps in Selecting Potential Sites

Soil maps prepared by the U.S. Department of Agriculture's Soil Conservation Service (SCS) may provide useful preliminary information about potential landfill sites. These maps identify soil profile characteristics to a depth of five feet.

The land's contour and subsurface formations are important in developing a landfill. Surface features will affect the landfill's layout and drainage characteristics. In addition to soil type, other important features such as roads, railroad tracks, buildings, and surface waters are shown.

Soil is used in landfill development for three purposes:

- **As cover:** Soil is used daily to cover the solid waste. It is also used when an area of the landfill is completed. The permeability of the final cover will greatly affect the quantity of leachate generated.
- **For migration control:** Soil is used to control the movement of leachate and methane gas away from the landfill. An impermeable soil will retard such movement; a permeable soil will provide less protection and may require installing additional controls in the landfill.
- **As foundational support:** The soil below and adjacent to the landfill must be suitable for construction. It must provide a firm foundation for liners, roads, and other construction activities.

The Soil Conservation Service (SCS) can provide data on the soil types of many, but not all, areas of the U.S.

The Soil Conservation Service (SCS) can provide data on the soil types of many, but not all, areas of the United States. Land with a potential for solid waste disposal can be located by determining the SCS limitations of the particular soil for landfilling. The SCS has defined each soil type as having “slight,” “moderate,” or “severe,” limitations for use as a landfill site.

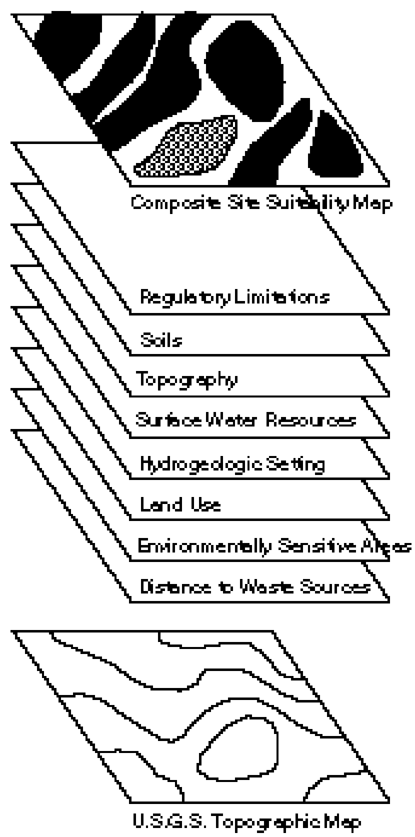
The fact that soil maps only describe the soil to a depth of five feet is a major limitation in using them for selecting potential sites. As a result, a site first judged suitable during work with the soil maps may be deemed unsuitable once data are collected at depths greater than five feet.

Tabulating Site Identification Data

When identifying potential sites, the best approach is to follow criteria defined by

- *the developer*
- *public officials*
- *interested citizens, and*
- *regulatory officials*

Figure 9-2
Examples of Map Overlays



Source: W. Lane and R. McDonald, "Land Suitability Analysis for Sanitary Landfill Siting," 1981

Several procedures may be used to collect and tabulate the necessary data. The most informal approach is to identify a list of potential sites based on personal knowledge of the area being studied. This approach limits the area being considered but presents a major handicap because other suitable areas may be overlooked.

One way of incorporating the various siting criteria is to prepare a series of map overlays. Each overlay identifies land areas with moderate or severe limitations in regard to a particular criterion. A USGS (U.S. Geological Service) quadrangle map is often used as the base map. The overlays, shown in Figure 9-2, are prepared on transparent plastic sheets placed over the base map.

The best approach for establishing the limitations ratings for each criterion is through a technical assessment conducted in combination with input from public officials, interested citizens, and regulatory officials. A unique criteria rating should be prepared for each proposed landfill development project to ensure that local concerns are addressed.

Once a map is prepared for each criteria the maps are assembled as overlays and the most suitable areas identified. Both graphical or computer techniques are available for assembling the data.

When using soil and site identification data, project developers should keep in mind that these sources do not provide absolute data, but only estimates or approximations of predominant soil types, depths, and other features. The estimates or approximations should be confirmed later by conducting soil borings if the potential site is otherwise found to be a good candidate for a landfill.

A well-planned siting program must include opportunities for public participation.

A well-planned siting program must include opportunities for public participation at appropriate times. Citizens may participate through public hearings, advisory committees, surveys, tours of established landfills, and public meetings in which small-group discussions between citizens and project planners are encouraged. The public may also be involved in publishing newsletters or issuing press releases to keep other residents informed about the program's progress. Chapter 1 provides additional information on public participation.

Determine Applicable Federal, State, and Local Requirements

The Resource Conservation and Recovery Act (RCRA)

State programs for landfill regulation are required by RCRA Subtitle D to incorporate the federal regulations.

The RCRA Subtitle D approach uses a combination of design and performance standards for regulating MSW landfills. USEPA's Subtitle D rule, published October 9, 1991, also establishes facility design and operating standards, groundwater monitoring, corrective action measures, and conditions (including financial requirements) for closing municipal landfills and providing post-closure care for them. A phased implementation of the regulations began on October 9, 1993. A current version of 40 CFR Parts 257 and 258 should be consulted to determine the applicable deadline dates for each type and size of municpal landfill. State programs for landfill regulation are required by Subtitle D to incorporate the federal regulations into the state codes. Recommended practices described in this chapter are consistent with Subtitle D rule requirements. State regulations under Subtitle D may be flexible to accommodate local conditions.

RCRA creates a framework for federal, state, and local government cooperation in controlling the disposal of municipal solid waste. While the federal landfill rule establishes national minimum standards for protecting human health and the environment, implementation of solid waste programs remains largely the responsibility of local, state, or tribal governments. Under the authority of RCRA, the USEPA regulates the following:

- **Location Restrictions:** airport safety, flood plains, wetlands, fault areas, seismic impact zones, unstable areas
- **Design Criteria:** liners and groundwater protection
- **Groundwater Monitoring and Corrective Action:** groundwater monitoring systems, groundwater sampling and analysis, detection monitoring, assessment monitoring, assessment of corrective measures, selection of remedy, implementation of corrective action program
- **Closure and Post-Closure Care:** closure criteria, post-closure care requirements
- **Financial Assurance Criteria:** financial assurance for closure, financial assurance for post-closure care, financial assurance for corrective action
- **Operating Criteria:** procedures for excluding hazardous waste, cover materials, disease vector controls, explosive gasses control, air criteria, access requirements, run-on / run-off control, surface water requirements, liquids restrictions, record keeping.

State and Local Requirements

State regulations vary widely, but usually landfill engineering plans are submitted to the appropriate state-level regulatory body for review and approval. State standards are ordinarily more extensive than RCRA standards and address concerns specific to a particular geographic region.

Five-to-seven-year planning and permitting periods are becoming more common.

Procuring the various permits required to open and operate a landfill may take several months to several years, especially if there is public controversy regarding the site. Five-to-seven-year planning and permitting periods are becoming more common. State or local governments may require:

- a solid waste landfill plan approval
- a conditional-use zoning permit
- a highway department permit (for entrances on public roads and increased traffic volume)
- a construction permit (for landfill site preparation)
- a solid waste facilities permit
- a water discharge / water quality control permit
- an operation permit (for on-going landfill operations)
- a mining permit for excavations
- building permits (to construct buildings on the landfill site)
- a fugitive dust permit
- an air emission permit
- a closure permit.

Additional Concerns

Waste disposal facility owners are being held responsible for environmental damage and cleanup, even after closure.

The regulatory standards should be viewed as minimum requirements that specify a baseline standard of design and performance. Waste disposal facility owners are being held responsible for environmental damage and cleanup many years after the disposal site began operation, and even following closure, under CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act), better known as Superfund. In addition, claiming compliance with regulatory standards has not been an effective defense against pollution damage claims.

Local governments may also have regulations affecting site identification. Many municipalities restrict certain activities in designated areas. Familiarity with the laws and regulations is not enough. The planner should establish a working relationship with the people who administer the regulations. These people can help interpret and apply the rules. Although zoning for a particular site can be changed by a governing board, disagreements between different jurisdictions and citizen opposition may prevent the development of a landfill in a certain area.

Assess Landfill Options for Energy and Materials Recovery

Landfill gas can be a useful source of energy.

Gas generated from landfills can have at least three uses: (1) as a boiler fuel, (2) as fuel for an engine-generator set to produce electricity, and (3) as a natural gas supplement, when first upgraded to pipeline quality. In industrial boilers, landfill gas is best used as a supplementary fuel. This allows the boiler to be fired continuously using other fuels if landfill gas becomes unavailable for some reason. Specifications for boiler gas focus on the absence of air or oxygen, compression, and transporting the gas to the boiler. Dewatering may also be necessary to accommodate climate and pipeline distance and configuration. Depending on the situation, gas as low as 20 to 30 percent methane can be used in boilers.

Landfill gas is also used to generate electricity. Many plants in the U.S. use compressed and dewatered landfill gas to fuel either gas turbines or reciprocating engines that drive electrical generators. In general, smaller plants tend to use reciprocating engines and larger plants tend to use gas turbines. To drive a generator, the gas must be at least 30 percent methane or have a minimum heating value of at least 300 Btu's per cubic foot.

The third use for landfill gas is as a supplement for natural gas. This requires removing carbon dioxide and trace gases to upgrade the landfill gas to 100 percent methane. The gas is then directed into a natural gas transmission system. The market for this gas is virtually inexhaustible and is easily accessible with natural gas transmission lines, which are often located in the vicinity of the landfills. Difficulties in reaching markets for this use of landfill gas are usually associated with the amount and cost of processing required to upgrade the gas to pipeline quality and gaining approval of the pipeline company.

Consider Final Site Use

The final use of the landfill site should be considered during the initial site decision phase in order to provide for the best use of the property. Good planning at the earliest possible stage will minimize costs and maximize the site's usefulness after closure.

Monitoring requirements, groundwater protection, gas migration control, and uneven settlement should be carefully considered if the land can be used productively after closure.

Many case studies have shown that land formerly used for solid waste disposal can be upgraded through proper design and implementation of innovative landfill concepts. An example is land that has been converted into an open-space park in a municipality where open space may be in short supply. Many landfills have been turned over to parks departments or conservation agencies for general public use after landfilling has been completed. Careful attention must be given to monitoring requirements, groundwater protection, gas migration control, and uneven settlement. If the landfill design provides for such constraints, however, the land can be turned into productive use when the landfill is completed. Improvements also need to be properly designed to avoid disturbance of design features in the closed landfill, such as leachate collection systems.

The best strategy is to plan for the eventual use of the site before the landfill is constructed and operated. An additional benefit of planning ahead is that stating a planned use during site selection may reduce possible opposition to a new landfill. Potential uses for closed MSW landfills are provided below:

- nature park
- recreation park
- wilderness area
- animal refuge
- golf course
- ski or toboggan hill
- parking lot

Final uses under consideration must be compatible with the post-closure care plan, with other nearby land uses, and with the limited ability of the landfill to support structures.

Planning is particularly important if future construction or building on or near the landfill site is anticipated. Design features such as location of structures requiring special support, recreational facilities requiring specific topography, and gas control systems to protect future buildings can be anticipated during landfill operation.

Depending on planned site use, factors that can be modified are cover thickness, slope, cover / waste ratio, degree of compaction, use of additives and cements, selective disposal, and setting aside undisturbed areas as structural pads. The consequences of changing plans for the landfill usually include costly modifications, such as the removal of settlement-prone cover and waste layers.

When identifying potential options for final landfill use, it is important that uses under consideration be compatible with the post-closure care plan, with other nearby land uses, and with the limited ability of the landfill to support structures. Most completed landfills are used for recreational purposes, such as golf courses, nature preserves, or ski hills. Consideration must also be given to compatibility with existing land forms, settlement allowances, landfill gas protection, drainage patterns, and open-space planning.

Determine Suitability of Sites

Site characterization will concern the geology and hydrogeology of a potential site or sites.

The next step in the site selection process is to conduct a more detailed investigation of those sites designated in the site identification process as being most suitable. Site characterization studies should be conducted at sites with the most desirable characteristics. Thorough site characterizations are conducted in two phases. The first phase involves collecting and reviewing as much information as can be found about the site. The second phase involves field investigation activities. Most of the new data collected will concern the geology and hydrogeology of potential sites. Such information helps planners determine aquifer depths, geologic formations, drainage patterns, depth to groundwater, groundwater quality and flow direction, and construction characteristics of on-site soils. Data about existing land use, surrounding land development, available utilities, highway access, political jurisdiction, and land cost are also tabulated.

Conducting Site Characterizations—Information Collection and Review

Before beginning a field investigation, developers should review all available information about the site. A thorough review will include the following:

- **A literature review:** including (1) research reports that provide findings of studies conducted on the site itself or on surrounding areas, (2) journal articles dealing with the site or surrounding areas, (3) studies and reports from local, regional, and state offices (geological surveys, water boards, environmental agencies, etc.), and (4) studies from federal offices such as the U.S. Geological Service or USEPA.
- **Gathering information from file searches:** Including (1) reports of previous site characterizations for the site, (2) geological and environmental assessment data from state and federal project reports, (3) previous site uses for disposal which may have resulted in contamination.

The documentation listed above is by no means a complete listing of data necessary to conduct a preliminary investigation. There are many other sources of documentation that may be available for review during the preliminary investigation. After completing the preliminary investigation, the hydrogeology of the site must be characterized.

Conducting Site Characterizations—Field Investigations

The conceptual model should be a reliable estimation of geologic and hydrogeologic conditions at the site.

The proposed site must be characterized to determine subsurface conditions. Site characterization studies consist of geophysical investigations, soil borings and test pits below and adjacent to the proposed site. The number, location, and depth of the soil borings are dictated by the hydrogeology of the site. The number of borings needed to accurately define conditions increases with the size and geologic complexity of the site. The result of the investigations will lead to the formation of a conceptual model. This model should be a reliable estimation of geologic and hydrogeologic conditions at the site.

The borehole program usually requires more than one round of drilling. The objective of the initial boreholes is to further define the conceptual model derived from research data. The borehole program should be designed as follows:

- Determine the initial number of borings and their spacing based on the information obtained during the preliminary investigation.
- As needed, install additional borings to provide more information about the site.
- Collect samples when changes in lithology occur. For boreholes that will be completed as monitoring wells, at least one sample must be collected from the interval that will be screened. As a boring is being advanced, a soils scientist or geologist will collect samples for testing. Normally, soil samples are tested for grain size distribution and moisture content and are classified by soil type.

Soils that may later be used for liners and landfill covers will also be tested for permeability, moisture content, moisture density relationship, and moisture strength factors. This data is used to prepare a boring log, as shown in Figure 9-3.

Some states' regulations specify the minimum number of borings for each site and a minimum number per acre.

Borings should extend below the expected base elevation of the landfill, and at least a portion of the boreholes should terminate below the water table. Selected borings should extend to bedrock unless the distances involved make it unreasonable. Monitoring wells can be constructed in the boreholes as part of the hydrogeologic study. Some states' regulations specify the minimum number of borings for each site and a minimum number per acre to reduce the chances of overlooking significant hydrogeologic features such as sand lenses or perched water.

Measuring static water elevations in wells helps to determine the horizontal and vertical groundwater gradients for estimating flow rates and flow directions. The water levels can be plotted and contoured on a map that also shows adjacent land uses. Superimposing flow lines on the contours shows where leakage from a potential landfill may migrate. An example is shown in Figure 9-4.

Geophysical techniques, either surface or down-hole, can be used to plan and supplement the subsurface borehole program. Down-hole techniques include electric logging, sonic logging, and nuclear logging. Surface geophysical techniques include seismic profiling, electromagnetic profiling, and resistivity profiling.

The final output of the site characterization phase of the hydrogeological investigation is a conceptual model, which consists of an integrated picture of the hydrogeologic system and the waste management setting. The final conceptual model must be a site-specific description of the vadose zone, the uppermost aquifer, and its confining units. The model should contain all of the information necessary to design a groundwater monitoring system.

Hydrogeologic studies are expensive and should be limited to sites with the most promising characteristics.

Other conditions may exist at proposed landfill sites. The presence of bedrock can impede excavation and greatly complicate groundwater protection. Sites with multiple soil layers and formations will require careful characterization as the landfill is being designed. When soil and groundwater limitations must be overcome, specialized site layout must be carefully implemented.

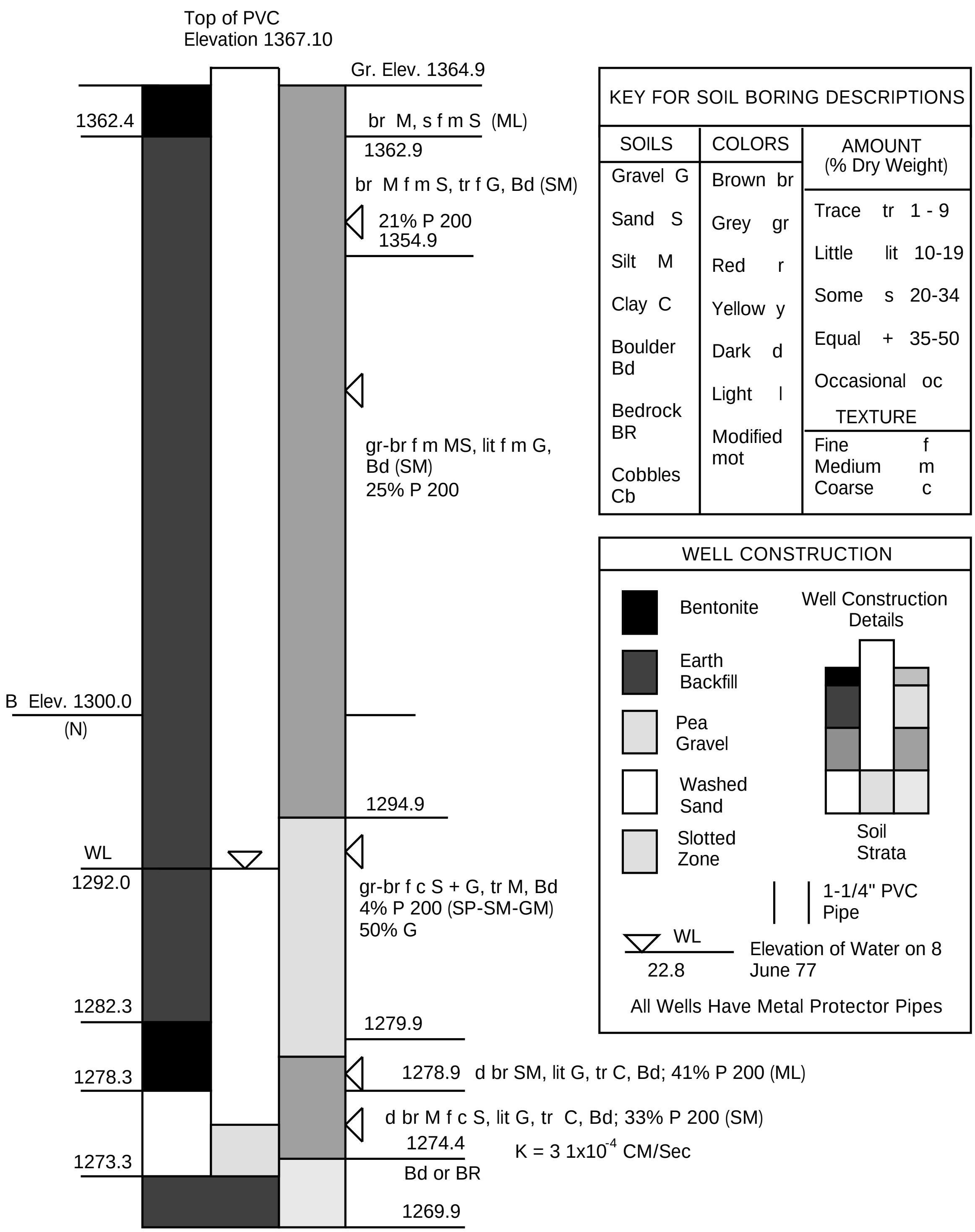
Hydrogeologic studies are relatively expensive to conduct and should, therefore, be limited to those sites with the most promising characteristics. A further cost concern is obtaining permission to do the testing without buying the property beforehand. One alternative is to purchase an option to buy, which gives the purchaser the right to buy the land within a specified period of time for a specified price. This allows time for testing and evaluating the results without commitment to purchasing the property.

The preliminary feasibility report should contain all of the pertinent information needed for determining which site to select. The report may suggest a preferred site or may leave this decision to the governing board of the unit of government or other organization that will be operating the landfill.

Once a site has been selected, a final feasibility report can be prepared and submitted to the appropriate agencies for approval. This is discussed in the following sections.

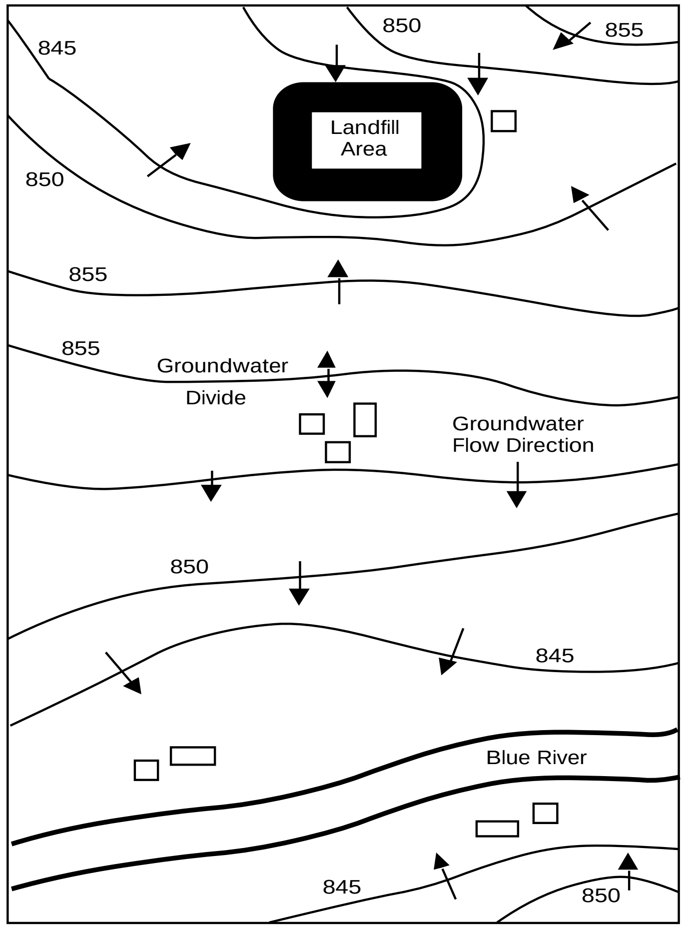
Figure 9-3

Example of Soil Boring Logs



Source: Department of Adult and Community College Education, North Carolina Sate University, reprinted from *Waste Age*, Correspondence Course articles 1991-1992

Figure 9-4
Example of Groundwater Contour Map



Source: P. O'Leary and P. Walsh, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course 1991-1992

The feasibility report should provide complete information to decision makers and regulatory authorities.

DEVELOPING THE FACILITY DESIGN

Preliminary Considerations

Selecting the Type of MSW Landfill

The major types of MSW landfill are the area and the canyon landfills. The area landfill is generally used in a rolling terrain where cover soil can be obtained from an area adjacent to the landfill itself. Through proper coordination, the cover soil is brought in as necessary to provide the various forms of cover and to prepare the berms. A typical area fill is shown in cross section in Figure 9-5.

A canyon fill is used in mountainous areas and may be considered a variation of the area landfill because cover is usually obtained from adjacent areas, rather than from the waste footprint. A canyon landfill tends to be deep. Total refuse depths in excess of 200 feet are common. Much of the difficulty in designing canyon landfills is routing traffic so it can reach the different elevations of the landfill as the working phase moves both over the area and also up the height of the landfill. Access involves a series of roads constructed adjacent to or on the landfill to elevate traffic to the working face. Other problems in designing canyon landfills are maintaining slope stability and preventing erosion.

Landfills can also be defined by the types of waste disposed of and the type of preprocessing done. Waste can range from food and yard trimmings or other decomposable materials to industrial wastes that are relatively inert, such as demolition debris. The design of the landfill must reflect the potential for groundwater contamination and gaseous emissions particular to the waste accepted for disposal. Preprocessing waste may consist of shredding, baling, or a combination of residuals from other processes. Preprocessing will change the characteristics of the waste and on-site handling. These considerations must be included in the design.

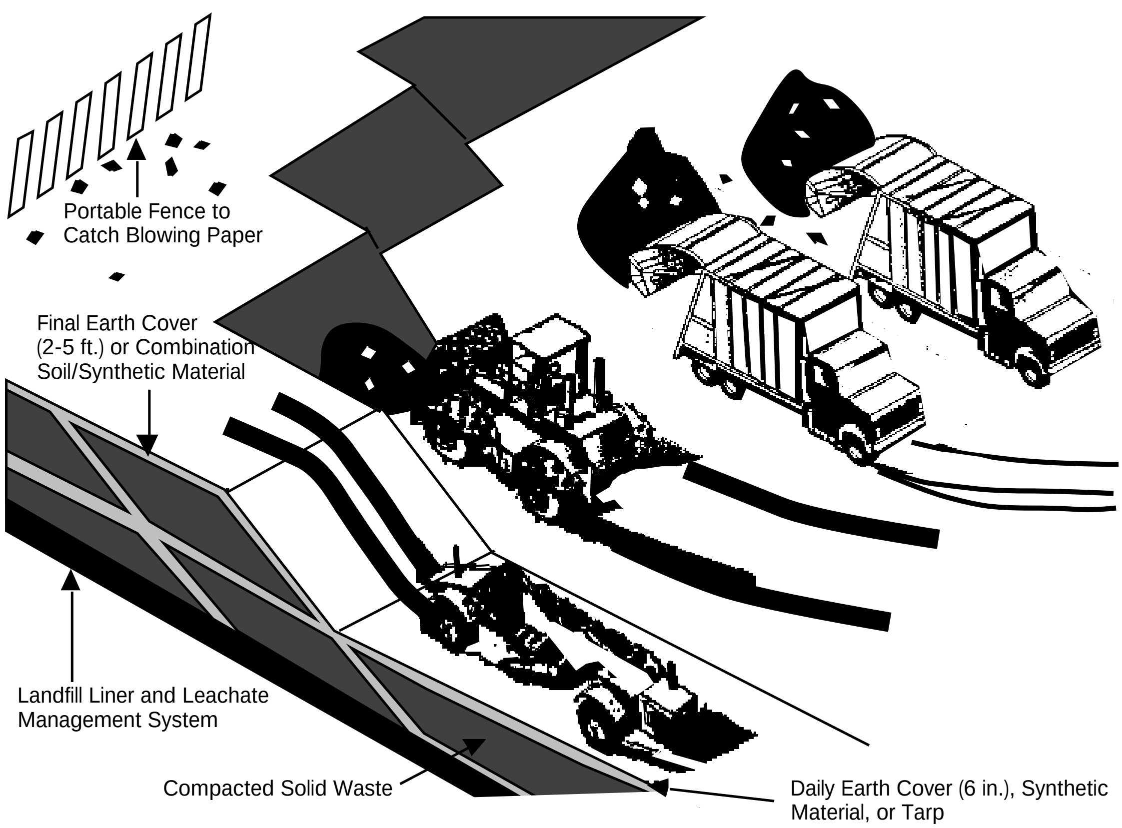
A unique combination of timing, site restrictions, waste characteristics, and regulatory and political factors force design teams to adapt as projects unfold.

The Design Process

It is not possible to outline a typical landfill design process and expect a given project to follow the specified sequence. Each project presents a unique combination of timing, site restrictions, and waste characteristics, along with regulatory and political factors that force the design team to adapt as the project unfolds. Nevertheless, certain points must be covered in the landfill design

Figure 9-5

The Area Method of Sanitary Landfilling



Source: P. O'Leary and P. Walsh, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course 1991-1992

process, and it is helpful to have an initial outline of a logical sequence of activities to follow. Such an outline is summarized in Table 9-3. Data collected during site selection will be incorporated into the site design, but changing conditions and the need for more detail may require re-evaluation and adding to previously collected data.

Public Participation in the Site Selection Process

See Chapters 1 and 2 for suggested approaches to facilitate public participation.

Concurrent with the design and permitting processes, public education and participation programs must be undertaken. The final stage of site selection is gaining public approval. Chapter 1, on public education, and Chapter 2, on siting, should be consulted for suggested approaches to facilitate public participation. Projects lacking public review or input until the design is completed may face substantial delays in the approval process.

Meeting Regulatory Standards

There are generally two types of federal, state, and local government standards: engineering design standards and performance standards. Engineering design standards are essentially building codes that describe how the facility must be built. An example might be requiring that new landfills have a six-foot-high fence surrounding them. The regulating bodies monitor compliance with these standards by reviewing the building plans and inspecting the landfill during construction. Performance standards are applicable over a facility's life and specify that a certain level of environmental control be achieved and maintained. For example, the state agency regulating groundwater quality may specify the maximum allowable concentration of a contaminant that may be present in the groundwater below or adjacent to the site. The site operator must incorporate the necessary control systems to achieve compliance with the groundwater standard. If the landfill as initially designed does not achieve compliance, then the operator must install additional protective systems.

The final use of the landfill must be considered during the design phase in order to provide for the best use of the property. Good planning at the earliest possible stage will minimize costs and maximize the site's usefulness after closure. The long-term alternative end uses will be limited and must be consistent with the approved closure plan.

General Design Considerations

The design package should include plans, specifications, a design report, and an operator's manual, all of which will be submitted to regulatory agencies.

The design package should include plans, specifications, a design report, and an operator's manual, all of which will be submitted to regulatory agencies. A cost estimate for in-house uses should also be submitted.

Plans and Specifications

Plans and specifications typically include the following elements:

- a base map showing existing site conditions with contour intervals of one foot to five feet and a scale of one inch equal to 50 feet to one inch equal to 200 feet
- a site preparation plan designating fill and stockpile areas and site facilities
- a development plan showing initial excavated and final completed contours in filling areas
- cross sections illustrating phased development of the landfill at several interim points
- construction details illustrating detailed construction of site facilities
- a completed site plan including final site landscaping and other improvements.

Table 9-3
Sanitary Landfill Design Steps

1. Determine solid waste quantities and characteristics
   a. Existing
   b. Projected
2. Compile information for potential sites
   a. Perform boundary and topographic surveys
   b. Prepare base maps of existing conditions on and near sites
      - Property boundaries
      - Topography and slopes
      - Surface water
      - Wetlands
      - Utilities
      - Roads
      - Structures
      - Residences
      - Land use
   c. Compile hydrogeological information and prepare location map
      - Soils (depth, texture, structure, bulk density, porosity, permeability, moisture, ease of excavation, stability, pH, CATION exchange capacity)
      - Bedrock (depth, type, presence of fractures, location of surface outcrops)
      - Groundwater (average depth, seasonal fluctuations, hydraulic gradient and direction of flow, rate of flow, quality, uses)
   d. Compile climatological data
      - Precipitation
      - Evaporation
      - Temperature
      - Number of freezing days
      - Wind direction
   e. Identify regulations (federal, state, local) and design standards
      - Loading rates
      - Frequency of cover
      - Distances to residences, roads, surface water and airports
      - Monitoring
      - Groundwater quality standards
      - Seismic and fault zones
      - Roads
      - Building coas
      - Contents of application for permit
3. Design filling area
   a. Select landfilling method based on:
      - Site topography
      - Site soils
      - Site bedrock
      - Site groundwater
   b. Specify design dimensions
      - Cell width, depth, length
      - Cell configuration
      - Fill depth
      - Liner thickness
      - Interim cover soil thickness
      - Final cover specifications
   c. Specify operational features
      - Use of cover soil
      - Method of cover application
      - Need for imported soil
      - Equipment requirements
      - Personnel requirements
4. Design features
   a. Leachate controls
   b. Gas controls
   c. Surface water controls
   d. Access roads
   e. Special working areas
   f. Special waste handling
   g. Structures
   h. Utilities
   i. Recycling drop off
   j. Fencing
   k. Lighting
   l. Washracks
   m. Monitoring wells
   n. Landscaping
5. Prepare design package
   a. Develop preliminary site plan of fill areas
   b. Develop landfill contour plans
      - Excavation plans (including benches)
      - Sequential fill plans
      - Completed fill plans
      - Fire, litter, vector, odor and noise controls
   c. Compute solid waste storage volume, soil requirement volumes, and site life
   d. Develop final site plan showing:
      - Normal fill areas
      - Special working areas
      - Leachate controls
      - Gas controls
      - Surface water controls
      - Access roads
      - Structures
      - Utilities
      - Fencing
      - Lighting
      - Washracks
      - Monitoring wells
      - Landscaping
   e. Prepare elevation plans with cross-sections of:
      - Excavated fill
      - Completed fill
      - Phase development of fill at interim points
   f. Prepare construction details
      - Leachate controls
      - Gas controls
      - Surface water controls
      - Access roads
      - Structures
      - Monitoring wells
   g. Prepare ultimate land use plan
   h. Prepare cost estimate
   i. Prepare design report
   j. Prepare environmental impact assessment
   k. Submit application and obtaining required permits
   l. Prepare operator's manual

Source: Adapted from Conrad et al., *Solid Waste Landfill Design and Operation Practices*, EPA Draft Report Contract, 1981

Design Report

A design report typically includes the following four major sections:

- a site description, which includes existing site size, topography, slopes, surface water, utilities, roads, structures, land use, soil, groundwater, exploration data, bedrock, and climatological information
- design criteria, which include solid waste types, volumes, and fill-area dimensions and all calculations
- operational procedures, which include site preparation, solid waste unloading, handling, and covering, as well as equipment and personnel requirements
- environmental safeguards, including the control of leachate, surface water, gas, blowing paper, odor, and vectors.

Public Involvement

The mechanisms chosen to facilitate public participation must be suited to the particular group from whom input is being sought.

Many of the permits needed before landfill design and operating plans are approved require that a public hearing be conducted to solicit input from interested parties. The firm or agency designing the landfill should also solicit input from individuals and groups who will be directly affected by the future landfill. The mechanisms chosen to facilitate public participation must be suited to the particular group from whom input is being sought. Such techniques include advisory committees, surveys, public meetings, and tours of similar facilities. Public hearings should be conducted after the public has been provided with details about the proposed facility and any concerns voiced by representatives of the community. Some communities establish technical and citizen advisory committees that participate in establishing goals and objectives and then help prepare evaluation criteria and the final landfill design.

State-Level Approval Process

Most states employ a multistage approval process similar to the following:

1. Initiate the required landfill siting regulatory review procedures.
2. Submit a feasibility (engineering) report to the state for approval.
3. Submit detailed engineering plans to the state.
4. Submit a final application for state landfill operating permits.

Additional Requirements

Other permits may be needed from local, state, and federal agencies.

In addition, federal and state legislation may require that an environmental impact statement be prepared.

After submitting applications and plans, the agency reviewing the proposal may have additional questions to be answered by the developer. Additional permits may be needed from local agencies, state agencies other than the one dealing specifically with landfills, and federal agencies, such as the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

The National Environmental Policy Act and similar legislation enacted by many states may require that a federal or state agency prepare an environmental impact statement. The purpose of the environmental impact statement is to disclose the nature of the proposed project, assess current and possible future environmental conditions, and to describe alternatives to the proposed action.

Developing the Site Layout

The landfill's layout will be strongly influenced by the site's geology. Of particular concern is the potential for gas and leachate migration and the suitability of the soil for landfill base and cover material. The site layout begins with geotechnical information, which includes data on the geology, hydrology, and soils at and around the site. These data are usually collected during the site-selection process, then supplemented during subsequent site investigation.

Many boring logs and additional cross sections are typically required to properly locate the waste disposal area within the site.

Soil-boring logs, as well as other data describing subsurface formations and groundwater conditions, are diagrammed to present an interpretation of the subsurface conditions at the planned landfill site. Figure 9-6 is a diagram of subsurface conditions along one cross section of a landfill under development. The soil-boring logs are shown, and the extent of each formation is extrapolated between the boreholes. The depths to bedrock and the groundwater table are also shown. Many more boring logs and additional cross sections at regular coordinate intervals in several (minimum of two) directions are typically required to properly locate the waste disposal area within the site under development.

Preparation of Drawings

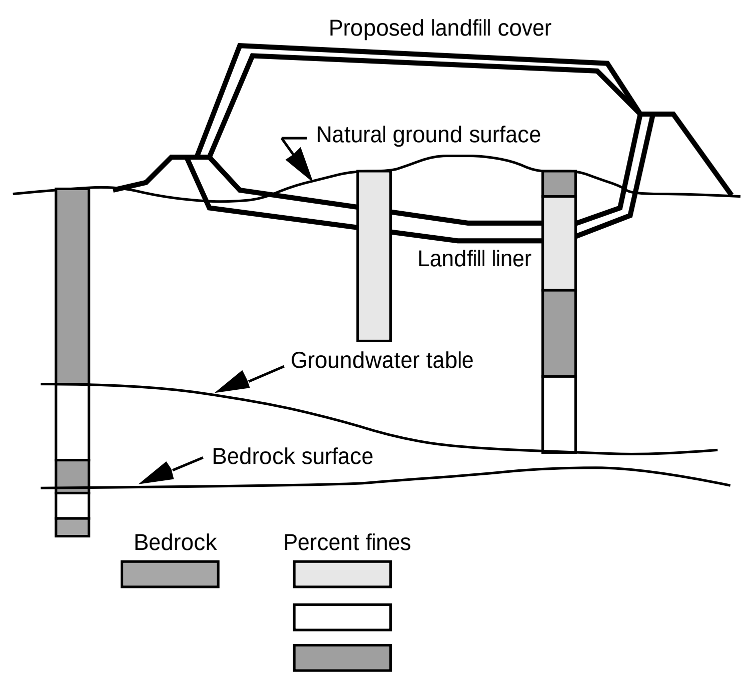
The base map usually shows the landfill location in relation to surrounding communities, roads, and other features. A site map shows the following features:

- contour lines drawn at two- or five-foot intervals
- clearly delineated property lines
- easements and rights-of-way indicated
- utility corridors, buildings, wells, roads, and other features identified
- drainage ways marked
- neighboring property ownership and land uses shown.

Contour maps show drainage patterns adjacent to and through possible disposal sites. Areas with excessive slope or direct overland flow from a potential site to surface waters must be carefully evaluated.

Figure 9-6

Subsurface Conditions Along a Cross Section of a Landfill Under Construction



Source: P. O'Leary and P. Walsh, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1991-1992

Subsurface formations and ground-water conditions will influence the landfill's design features in the leachate collection system and liner requirements. A formation's geotechnical characteristics will determine its suitability as a construction material.

Subsurface formations and groundwater conditions influence the landfill's design features in the leachate collection system and liner requirements. A formation's geotechnical characteristics will determine its suitability as a construction material.

The site plans should describe landfill development in sequence, showing in chronological order which features or phases are to be developed. Development is usually planned for the landfill to be constructed and operated in phases of one to two years each. Dividing the project into phases minimizes the amount of open landfill surface and reduces the potential for precipitation to accumulate in the site. As each phase is completed, that portion of the landfill can be closed and final cover material placed over the waste. A final advantage of phasing is that it makes premature closure of the landfill more practical and economical in the event of an environmental problem. In a well-planned phase development, the landfill's end use can be implemented in the completed sections while other areas are still being used for disposal.

Concurrent with the development of plans for liners, covers, service roads, and embankments, soil cut-and-fill balances (see glossary) must be calculated. The best designs minimize the transfer of soil at the site. Substantial volumes of earth will be required for cover material and possibly for liners.

Some regulatory agencies mandate the construction of screening berms or fences around the active areas of a landfill. The extra soil needed for berm construction must be accounted for when planning excavation work. The height of the berms will depend upon the lines of sight into the landfill from adjacent areas.

When practical, the phases should be laid out so that excavated soil is used immediately. When stockpiling is necessary, the work should be organized so that stockpiled soil may be left undisturbed until needed or be used to surcharge completed areas. Stockpiled soil should be covered whenever possible to prevent erosion from wind and precipitation.

After completion of the phasing diagrams and earth work balances, a table should be prepared summarizing the waste disposal and earth volumes that will be contained within each phase of the landfill.

Operating Plans

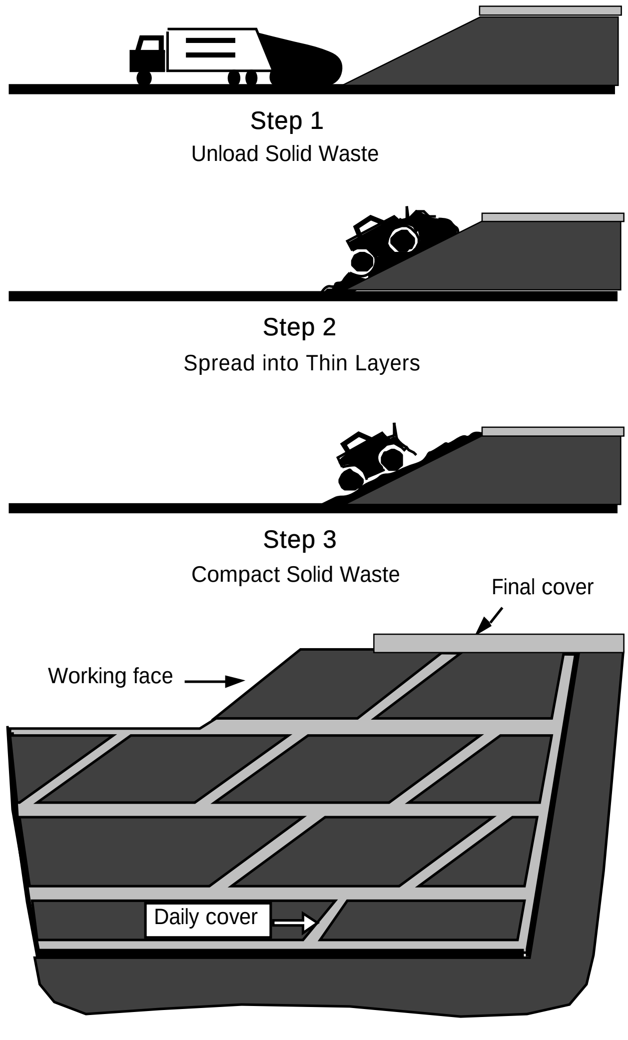
Determining Working Face and Phase Dimensions

The operating plan should describe all of the activities that will occur at the facility.

The operating plan should describe, in detail, the configuration of the working face of the landfill. Figure 9-7 illustrates a typical cross section of a portion of a municipal landfill, including the "working face," and helps to define terms. The "working face" is the area presently being worked, with new refuse being deposited and compacted into it. Once the working face has been completed and daily cover material provided, it is a completed cell or "daily cell." A "lift" is composed of the adjacent daily cells that form one layer of the landfill. Lift thicknesses are generally 8 to 20 feet. Larger landfills that accept more refuse per day have higher lift thicknesses. "Daily cover material," as shown in Figure 9-7, is applied over the working face and can extend over the horizontal surface at the top of each daily cell, depending on how long the cover will be exposed to the environment. If the landfill is not expected to receive additional wastes, closure activities must begin within 30 days of the final receipt of waste. The requirement to begin closure ensures that a proper cover is installed at the landfill.

The minimum width of the working face or daily cell should be at least wide enough to accommodate as many trucks or vehicles as are expected to be at the landfill at a given time. Typically, 10 to 15 feet per truck or vehicle is used for design purposes. Clearly, it is not a good operating practice to have extremely wide working faces to accommodate the peak flow of trucks that may occur once or twice a day. A tradeoff must be made between the width of the working face and the area needed to queue vehicles entering the site during peak hours. The

Figure 9-7
Solid Waste Placement and Compaction



Source: P. O'Leary and P. Walsh, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course 1991-1992

working face should be kept as small as possible because it is this area that can attract birds, provide visual problems for passersby, and be a source of blowing paper. Keeping freshly deposited refuse in a well-defined and small working face is a good indication of a well-operated landfill.

Phasing diagrams show the landfill's evolution through different stages.

Phase Diagrams

The site plan should illustrate the chronological order for developing the features. In a well-planned phased development, the landfill's end use can begin on completed sections while other areas in the landfill are still being used for disposal.

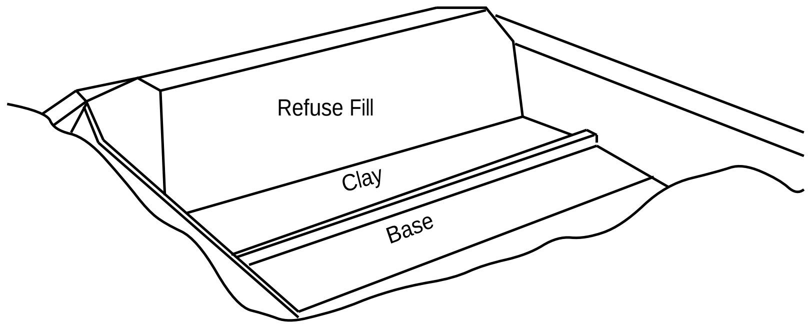
Phasing diagrams show the evolution of the landfill at different stages through the life of the site (see Figure 9-8). They should be developed for key times in sufficient detail to ensure that the operator knows what is to be done at any point. The engineers and management must be assured that the site is proceeding according to plan and contracts can be let or finances arranged for

Regulatory bodies must be assured that landfill operators are following the plan and the site will be completed as designed at the agreed-upon time.

construction activities. Regulatory bodies must also be assured that landfill operators are following the plan and the site will be completed as designed at the agreed-upon time. The dimensions of each phase are determined by several factors. Generally, each phase accommodates 2 to 3 years of refuse volume.

Figure 9-8

Landfill Construction Plan: Intermediate Phase



Source: P. O'Leary and P. Walsh, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course 1991-1992

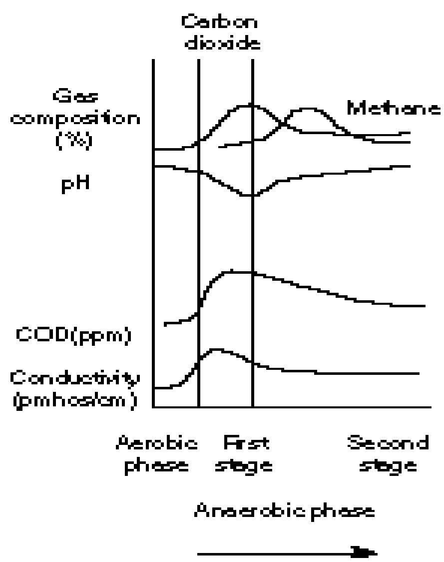
Leachate Management

Leachate is a liquid that has passed through or emerged from the waste in a landfill. It contains soluble, suspended, or miscible materials removed from the waste.

Refuse contains decomposable matter, as well as the nutrients and organisms that promote decomposition. The limiting factor controlling the amount of decomposition taking place in municipal solid waste is usually the availability of moisture. The decomposition of solid wastes in an MSW landfill is a complex process. It may be characterized according to the physical, chemical, and biological processes that interact simultaneously to bring about the overall decomposition. The three phases of decomposition are shown in Figure 9-9. The by-products of all these mechanisms are chemically laden leachate and landfill gas.

Figure 9-9

Phases of Solid Waste Decomposition



Sources: (a) Fa[illegible] 2; (b) Stanforth, Ham, Anderson and Stegmann 1979, *Journal of the Water Pollution Control Federation*, Vol. 51

Leachate is a liquid that has passed through or emerged from the waste in a landfill. It contains soluble, suspended, or miscible materials removed from such waste. Table 9-4 shows the changes in leachate composition that occur as a landfill proceeds through the various decomposition phases. It is imperative, therefore, when designing leachate collection and treatment facilities to consider the concentrations and variability of leachate with regard to its many constituents.

Leachate generation rates depend on the amount of liquid originally contained in the waste (primary leachate) and the quantity of precipitation that enters the landfill through the cover or falls directly on the waste (secondary leachate).

Climate, topography, landfill cover, vegetation, and waste types affect leachate generation.

Factors Affecting Leachate Generation

These factors influence leachate generation at landfills:

- **Climate:** Climate at the site significantly influences the leachate generation rate. All other factors being equal, a site located in an area of high precipitation can be expected to generate more leachate.
- **Topography:** Topography affects the site's runoff pattern and the amount of water entering and leaving the site. Landfills should be designed to limit leachate generation from areas peripheral to the site by diverting surface-water "run-on" away from the site and by constructing the landfill cover area to promote runoff and reduce infiltration. All areas of a landfill should maintain at least a two percent grade over the

Table 9-4

Changes in Leachate Compositiion in Different Stages of a Landfill

Parameters with differences between acetic and methanogenic phase

Acetic phase	Average	Range
pH	6.1	4.5-7.5
BOD_5 (mg/l)	13000	4000-40000
COD (mg/l)	22000	6000-60000
BOD_5/COD	0.58	—-
$S0_{4\ (mg/l)}$	500	70-1750
Ca (mg/l)	1200	10-2500
Mg (mg/l)	470	50-1150
Fe (mg/l)	780	20-2100
Mn (mg/l)	25	0.3-65
Zn (mg/l)	5	0.1-120

Methanogenic phase		
pH	8	7.5-9
BOD_5 (mg/l)	180	20-550
COD (mg/l)	3000	500-4500
BOD_5/COD	0.06	—-
SO_4 (mg/l)	80	10-420
Ca (mg/l)	60	20-600
Mg (mg/l)	180	40-350
Fe (mg/l)	15	3-280
Mn (mg/l)	0.7	0.03-45
Zn (mg/l)	0.6	0.03-4

Parameters for which no differences between phases could be observed

	Average	Range
Cl (mg/l)	2100	100-5000
Na (mg/l)	1350	50-4000
K (mg/l)	1100	10-2500
Alkalinity (mg $CaC0_3$/l)	6700	300-11500
NH_4 (mg N/l)	750	30-3000
OrgN (mg N/l)	600	10-4250
Total N (mg N/l)	1250	50-5000
$N0_3$ (mg N/l)	3	0.1-50
$N0_2$ (mg N/l)	0.5	0-25
Total P (mg P/l)	6	0.1-30
A0X (ug Cl/l)*	2000	320-3500
As (ug/l)	160	5-1600
Cd (ug/l)	6	0.5-140
Co (ug/l)	55	4-950
Ni (ug/l)	200	20-2050
Pb (ug/l)	90	8-1020
Cr (ug/l)	300	30-1600
Cu (ug/l)	80	4-1400
Hg (ug/l)	10	0.2-50

*adsorbable organic halogen

Source: Ehrig, H.J., "Water and Element Balances of Landfills," in *Lecture Notes in Earth Sciences: The Landfill*, 1989

Table 9-5
Impact of Soil Surface on Water Runoff

Surface and Slope	Runoff in Percent	Coefficient
Grassy/Sandy Soil		
Flat	2 %	0.05 to 0.10
Average	2-7 %	0.10 to 0.15
Steep	7 %	0.15 to 0.20
Grassy/Heavy Soil		
Flat	2 %	0.13 to 0.17
Average	2-7 %	0.18 to 0.22
Steep	7 %	0.25 to 0.35

Source: D. G. Fenn et al., *The Use of the Water Balance Method for Predicting Leachate Generation from Solid Waste Disposal Sites, 1975*

waste at all times to prevent ponding of surface water. Table 9-5 shows the difference in runoff that will occur for different soils and slopes.

- **Landfill cover:** Landfill cover at the site affects the amount of water percolating into the landfill to form leachate. As the permeability of the soil used for final cover increases, leachate production rates increase. Consequently, to reduce the amount of leachate, modern design requires the use of low-permeability clays or geosynthetic membranes in final cover configurations.
- **Vegetation:** Vegetation plays an integral part in leachate control. It limits infiltration by intercepting precipitation directly (thereby improving evaporation from the surface) and by taking up soil moisture and transpiring it back to the atmosphere. A site with a poor vegetative cover may experience erosion that cuts gullies through the cover soil and allows precipitation to flow directly into the landfilled waste.
- **Type of waste:** The type of waste and the form that it is in (bulk, shredded, etc.) affect both the composition and quantity of leachate. Wetter wastes, for example, will generate more leachate.

The amount of leachate generated will affect operating costs for leachate collection and treatment.

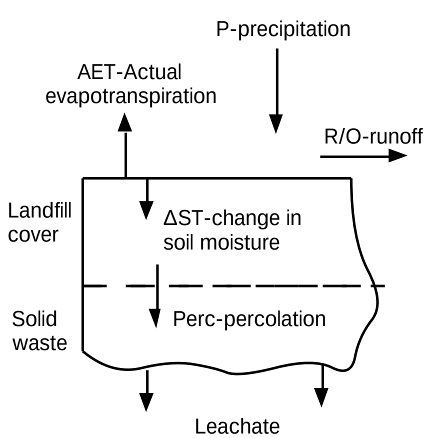
Predicting Leachate Production Rates

Good landfill design requires predicting the amount of leachate that will be produced. The amount of leachate generated will affect operating costs if leachate collection and treatment are provided. The amount of leachate formed also affects the potential for liner leakage (to be calculated later) and hence to the potential for groundwater contamination. It also affects the cost of post-closure care after the landfill is closed.

Predicting leachate formation requires water-balance calculations. The water-balance equation is given and the terms illustrated in Figure 9-10. The equation estimates the amount of water from rain or melting snow that will percolate through the landfill cover. Over time, the volume of percolating water will nearly equal the volume of leachate produced. There may be a lag between the time percolating water enters the fill material and the time leachate emanates continuously from the base of the fill. During this lag period, the solid wastes increase in moisture content until their field capacity is reached (field capacity is defined as the moisture content of the waste above which moisture will flow under the influence of gravity). Some leachate will be generated intermittently (almost immediately in wet climates), because of water channeling through the wastes. Once field capacity is achieved, however, leachate production should be more consistent.

The USEPA, in cooperation with the Army Corps of Engineers Waterways Experiment Laboratory, has prepared a computer program that calculates the water balance. The *Hydrologic Evaluation of Landfill Performance* (HELP) Model version 3.0 has weather records in data files and offers options for predicting leachate generation under many combinations of cover conditions. A portion of the output from a typical computer simulation is shown in Table 9-6.

Figure 9-10
Water Balance Equation



PERC = P - AET R/O - ΔST

Source: D. G. Fenn et al., *The Use of the Water Balance Method for Predicting Leachate Generation from Solid Waste Disposal Sites, 1975*

The HELP Model is designed to model layered cover systems to find the most effective combination. This program is available for use with a personal computer. For more information or to order the software, contact the US EPA, 26 West Martin Luther King Drive, Cincinnati, OH 45260; (513) 569-7871.

Table 9-6

Output from HELP Model

Projected Average Monthly Totals in Inches Based on 20 Years of Weather Records

	Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
Precipitation						
Totals	1.88	1.32	2.41	3.91	3.22	3.67
	4.98	3.87	3.05	3.01	2.09	1.95
Runoff from cover						
Totals	0.009	0.001	0.002	0.023	0.018	0.022
	0.129	0.026	0.031	0.058	0.001	0.000
Evapotranspiration from cover						
Totals	0.507	0.853	1.599	2.527	2.633	4.210
	4.954	4.198	2.256	1.371	0.709	0.527
Lateral drainage from drainage layer						
Totals	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000
	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000
Percolation through landfill clay cap layer						
Totals	0.8747	1.1013	1.0550	1.3568	0.9472	0.4574
	0.3671	0.0436	0.2371	0.4947	0.8001	0.9318
Leachate collected from drainage layer above landfill liner						
Totals	0.4432	0.4259	0.5042	0.5342	0.5997	0.5818
	0.5841	0.5395	0.4795	0.4804	0.4673	0.4892
Leachate collected from drainage layer above landfill liner						
Totals	0.0970	0.0884	0.0980	0.0945	0.0989	0.0957
	0.0959	0.0959	0.0922	0.0959	0.0943	0.0990

Projected Average Annual Totals for 20 Years

	Inches	Cu.Ft./Acre	Percent
Precipitation	35.37	128384	100.00
Runoff from cover	0.321	1165	0.91
Evapotranspiration from cover	26.342	95623	74.48
Lateral drainage from cap drainage layer	0.0005	2	0.00
Percolation through landfill clay cap layer	8.6668	31461	24.51
Leachate collected from drainage layer above landfill liner	6.1290	22248	17.33

Source: P. O'Leary and P. Walsh, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1991-1992

Regulatory Controls for Leachate Management

RCRA Subtitle D regulations established national standards for MSW; states with approved Subtitle D programs may allow variances to these requirements.

RCRA Subtitle D regulations establish a timetable for incorporating liners, leachate control systems, and final cover systems into the design of new municipal solid waste landfills. A current version of 40 CFR Parts 257 and 258 should be consulted to determine the applicable implementation dates. The particular type of design varies depending on the characteristics of the particular location. All liner systems incorporate leachate control systems in their design. States with approved Subtitle D programs may allow variances to these requirements.

The purpose of lining an MSW landfill is to prevent leachate from migrating from the site and entering an aquifer. A liner is a hydraulic barrier that prevents or greatly restricts migration of liquids, thus allowing leachate to be removed from the unit by the leachate control system. Liners function by two mechanisms: (1) they impede the flow of leachate into the subsoil and aquifers, and (2) they adsorb or attenuate pollutants, thus retarding contaminant migration. This adsorptive or attenuating capability depends largely on the chemical composition of the liner material and its mass. Most liner materials function by both mechanisms, but to different degrees, depending on the type of liner material and the nature of the liquid to be contained. Liners may be grouped into two major types: synthetic (flexible membrane) liners and natural (soil or clay) liners.

There are various types of liners in use, including compacted native and imported soils, compacted mixtures of native soils and bentonite, and flexible membrane liners. Flexible membrane liners are the least permeable liners, but have little capacity to attenuate dissolved pollutants. Natural liners can have a large capacity to attenuate materials of different types, but they are considerably more permeable than flexible membrane liners. A combination of both types of liner materials is referred to as a composite liner. Composite liner systems are more effective than either a single component flexible membrane liner or a soil liner. A composite liner can provide added protection to ensure that contaminant migration is controlled. The flexible membrane liner portion of the liner increases leachate collection efficiency and provides a more effective hydraulic barrier. The soil component provides support for the flexible membrane liner and the leachate collection system and acts as a back-up in the event of a flexible membrane liner failure.

The RCRA Subtitle D MSW landfill regulations require that new MSW landfills and expansions of existing MSW landfill facilities be constructed with a composite liner and a leachate collection system or meet a groundwater protection performance standard.

The RCRA Subtitle D MSW landfill regulations require that new MSW landfill facilities and expansions of existing MSW landfill facilities be constructed with a composite liner and a leachate collection system or meet a groundwater protection performance standard. The leachate collection system must be designed to maintain a leachate depth over the liner of less than 30 centimeters. The composite liner specified in the regulations is a system consisting of two components: the upper component is a flexible membrane liner installed in direct and uniform contact with a compacted soil, which forms the lower component. The flexible membrane liner must be at least 30 mils thick. If the flexible membrane liner is high-density polyethylene, the thickness must be a minimum of 60 mils. The compacted soil liner must be at least two feet thick and must have a hydraulic conductivity of no more than 1×10^{-7} centimeters per second.

The groundwater protection performance standard for landfills specifies that contaminant concentrations in groundwater flowing away from the landfill cannot exceed the amounts shown in Table 9-7. The point of measurement may be located from the waste unit boundary up to 150 meters (492 feet) from the boundary. Groundwater quality computer models are used to simulate contaminant movement, both concentration and extent, away from a planned landfill. The design of the landfill components is adjusted until compliance with the standards shown in Table 9-7 is demonstrated. The output from the models is usually a map showing changing parameter concentrations over time.

Extensive input data is needed to accurately run the models. Information required includes leachate characteristics, liner or base soil factors, geologic data, existing groundwater flow information, and interaction coefficients for leachate and materials underlying the proposed landfill. Several different modeling approaches may be necessary to characterize flow and contaminate movement away from a planned landfill towards the compliance boundary.

Table 9-7
Groundwater Protection Performance Standards

Chemical	Max. Concentration Limit (mg/l)	Chemical	Max. Concentration Limit (mg/l)
Arsenic	0.05	Lindane	0.004
Barium	1.0	Lead	0.05
Benzene	0.005	Mercury	0.002
Cadmium	0.01	Methoxychlor	0.1
Carbon tetrachloride	0.005	Nitrate	10.0
Chromium (hexavalent)	0.05	Selenium	0.01
2,4-Dichlorophenoxy acetic acid	0.1	Silver	0.05
1,4-Dichlorobenzene	0.075	Toxaphene	0.005
1,2-Dichloroethane	0.005	1,1,1-Trichloromethane	0.2
1,1-Dichloroethylene	0.007	Trichloroethylene	0.005
Endrin	0.0002	2,4,5-Trichlorophenoxy acetic acid	0.01
Fluoride	4.0	Vinyl Chloride	0.002

Source: USEPA

Landfill Liner System Components

Landfill liner systems consist of several components that control leachate movement off site. Figure 9-11 illustrates several configurations.

Clay Liners

Liner materials must be carefully tested during installation.

Regulatory agencies usually require that the soil liner have a permeability of less than 10^{-7} centimeters per second. To achieve final liner permeabilities that are consistently this low, tests must be conducted to determine the optimum moisture content and degree of compaction effort needed during construction of the liner.

Additional specifications are designed to ensure that the landfill is successfully constructed. See, for example, the Wisconsin specifications in Table 9-8.

Flexible Membrane Liners

Landfill designs may call for flexible membrane liner systems for several reasons: to overcome known leakage through clay liners, to save site volume for refuse instead of clay, and to overcome costly importation of clay if suitable clay is not locally available. Many kinds of flexible membrane liners are available for containing different kinds of liquid wastes. Design considerations include ensuring compatibility with the waste, developing a structurally sound design, providing good seaming, providing a firm base free of debris or sharp objects under the liner, maintaining construction quality control, and protecting the liner after construction. Flexible membrane liners can be used as the “impermeable” layer, and geonets can be used to facilitate drainage to a collection pipe. A typical flexible membrane liner thickness is 30 to 80 mils (0.030 to 0.080 inch).

Table 9-8
Wisconsin Clay Liner Specifications

Slope	
	For base minimum 2-4%
	For side slopes maximum 3:1
Drainage blanket	
	Clean sand/gravel minimum 12" thick
Clay material specs	
	Minimum 50% P200
	LL >/= 30
	PL >/= 15
	Permeability–maximum 1x10-7 cm/sec
	Clay fraction or CEC varies
Liner compaction	
	95% standard proctor
	90% modified proctor

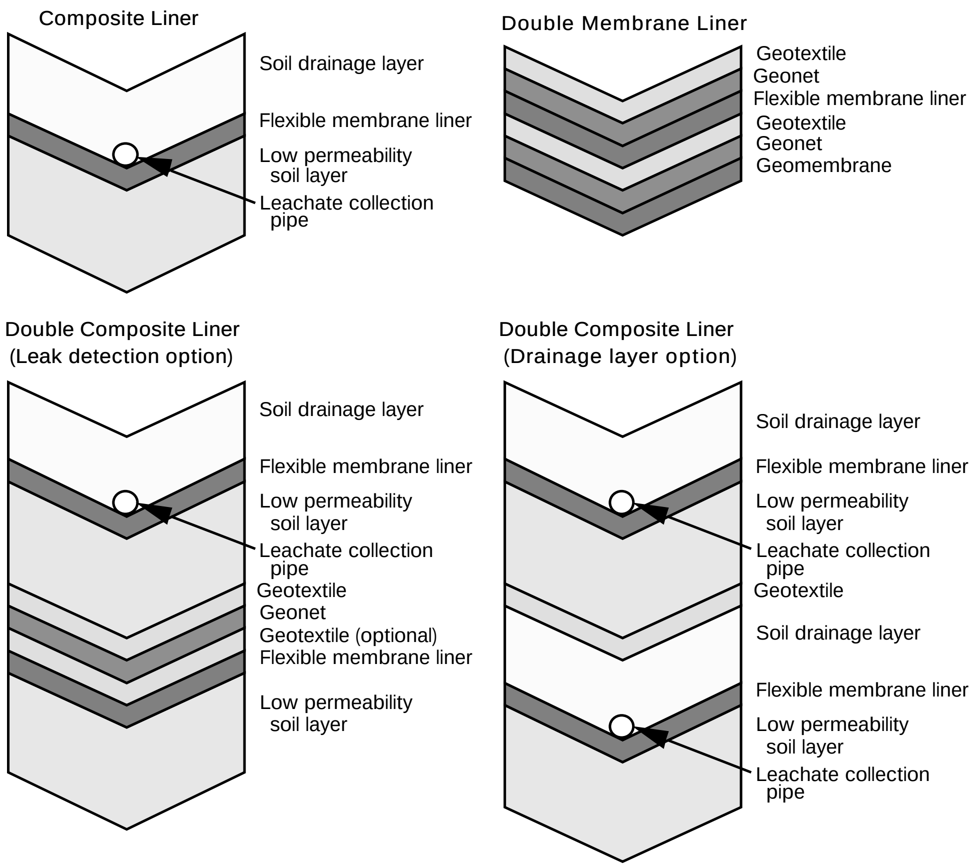
Source: G. Mitchell, 1994

A concern when relying on synthetic liners is that chemical interactions may affect the liner's integrity. Certain waste materials are known to degrade certain types of liners. Testing flexible membrane liners with MSW leachate has shown that most materials resist chemical attack under most conditions. USEPA Method 9090 was developed for hazardous waste landfills and in extreme cases could be used for MSW landfills. (See USEPA, SW-846, 1994 for further information.) This method involves an evaluation of changes in the flexible membrane liner material when immersed in leachate.

Leachate Collection Systems

The effectiveness of a leachate collection system is dependent on the design of the liner and the collection pipes. Layout of the liner and pipe network system varies, depending on the overall landfill area, phase shapes, and overall slope or topography. The slope of the liner should be at least 2 percent, and preferably 4 percent or more, to promote lateral flow of leachate to collection pipes, and pipes should be sloped at 1 percent minimum to ensure leachate flow and prevent accumulation at low spots along the pipeline.

Figure 9-11
Examples of Landfill Liner Systems



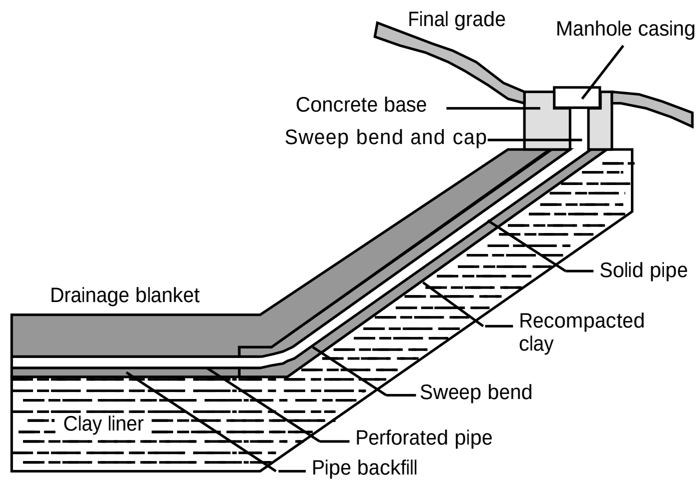
Source: P. O'Leary, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, 1994

The leachate management system consists of the liner, leachate collection system, and leachate treatment process.

The pipe is placed in a trench or directly on the liner at the low points. The trench should be backfilled with gravel and the pipe must be well-supported to avoid crushing. The gravel may need to be protected by a geotextile to avoid plugging by fine-grained material in any overburden layers. Figure 9-12 shows a typical configuration providing access to pipes in the network for cleaning. Access can be direct from the surface or by manholes placed in the landfill. Because all manholes accumulate gas and are subject to shifting and settling, they can pose safety and maintenance problems.

Figure 9-12

Typical Leachate Collection System Showing Access to Pipes for Cleaning



Source: P. Kmet, 1994

Leachate Treatment Processes

Leachate treatment options include on-site treatment, discharge to a municipal sewage treatment plant, or a combination of these approaches. Limited studies have indicated that another method, leachate recirculation, has certain benefits, which include increasing the rate of waste stabilization, improving leachate quality, and increasing the quantity and quality of methane gas production. Leachate recirculation also provides a viable on-site leachate management method. Federal requirements allow leachate recirculation at landfills that are designed and equipped with composite liners and leachate collection systems constructed to maintain less than a 30 cm depth of leachate over the liner.

Leachate can be treated on or off-site but the treatment process must be carefully developed to guarantee a successful system. The most common leachate treatment option is discharge to municipal sewage treatment plants. Since leachate strengths are significantly greater than normal municipal wastewaters, care must be taken to avoid overloading the plant. Studies have shown that greater than a 2 percent hydraulic loading of a sewage treatment plant with leachate will disrupt its operations.

A scheme for leachate treatment options as a function of leachate strength is shown in Figure 9-13. Chemical precipitation for high-strength acidic leachate is commonly achieved by adding lime.

For a leachate of high BOD (biological oxygen demand), such as those typically found in a young landfill, anaerobic biological treatment is useful be-

The options for leachate treatment must be carefully evaluated.

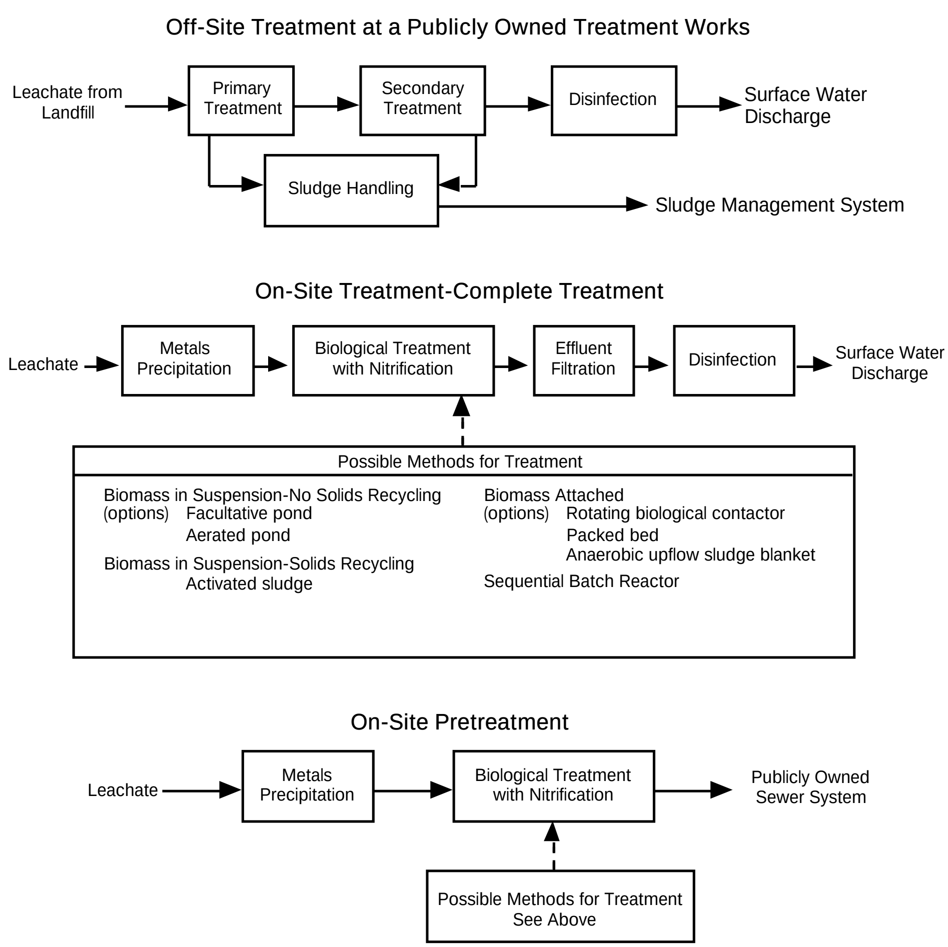
cause of its energy efficiency and low sludge generation rate. A 90 percent or more reduction in BOD can be expected using this method.

Leachate of medium BOD levels or pretreated leachate may be treated in aerobic biological systems, including activated sludge, rotating biological contractors, or sequenced batch units. Reduction of 90 percent or more of BOD, suspended solids, and precipitated metals is accomplished, but energy consumption may be high and comparatively large amounts of sludge are produced.

An aeration or facultative pond can be used to polish leachate treated by other methods, if the leachate has not yet reached a contaminant level suitable for discharge. Ponds can also be used to treat relatively low-strength leachates with BOD less than 100 mg/l. Such ponds may have surface aerators depending on the BOD, retention time, and configuration.

These systems are adequate for discharge to a Public Owned Treatment Works (POTW), if the POTW cannot, or for some reason will not, accept leachate directly from the landfill. If the leachate is to be discharged to surface water, additional treatment consisting of activated carbon adsorption, filtration, or reverse osmosis processes will be required, and air stripping or chemical precipitation may also be needed. A discharge permit will also be required.

Figure 9-13
Leachate Treatment Options



Source: G. Farquhar, 1994

The Natural Attenuation of Leachate

Many existing landfills do not have liners or have liners that can not completely contain the leachate. The chemicals in leachate that escape from the landfill base may undergo a variety of conversion and destruction reactions as they pass through the soil and into the underlying formations (a process called attenuation). For example, as leachate moves through a clay soil, most of the heavy metals (such as lead, arsenic, zinc, cadmium, and mercury) are retained by the soil. The ability of each soil to attenuate leachate is different, and not all elements or compounds are equally removed or reduced in concentration.

The unpredictable concentrations of leachate constituents, plus weather-related leachate generation surges and variations in subsurface conditions, make it extremely difficult to predict the degree of protection that natural attenuation will accomplish. The result is that landfills now incorporate means for containing and controlling leachate within the site, relying on natural attenuation only as a backup measure to protect groundwater quality. Existing landfills which have groundwater contamination levels exceeding RCRA Subtitle D limitations will be subject to remediation requirements.

Groundwater Quality Assessment

Monitoring Wells

Groundwater monitoring systems are required for new, existing, and lateral expansions of existing landfills. The monitoring is necessary to determine groundwater quality at a facility and to determine whether there has been a release of contaminants through the base of the landfill. All new landfills must have a groundwater monitoring system installed before any wastes are placed in the landfill. The schedule for installing a groundwater monitoring system at existing facilities depends on the location of the landfill with respect to a drinking water source or other state priorities. All units subject to the requirements will have to have the groundwater monitoring system in place by October 9, 1996.

Monitoring wells must be cased in a manner that maintains the integrity of the borehole and must be maintained to meet the design specifications. The number, spacing, and depths of the wells should be based on site-specific characteristics. The wells must also be constructed to facilitate the collection of groundwater samples. These two requirements are closely related. Great care must be taken when selecting well construction materials or sampling devices. Materials that may react with groundwater or contaminate samples should not be used.

The casing, associated seals, and grout protect the integrity of a borehole and minimize the hydraulic communication between zones. Materials that are not compatible with subsurface conditions can cause false or misleading detections, or non-detections, of analytes.

The techniques used to withdraw groundwater samples from a well must be based on considerations of the parameters to be analyzed in a sample. To ensure that the sample is representative of groundwater in the formation, physical alterations of the sample must be kept to a minimum. It is important to select sampling equipment that will maintain sample integrity. The sampling equipment must be constructed of inert materials that will not alter analyte concentrations or react with, sorb, or desorb the analytes.

To achieve accurate results, groundwater monitoring wells must be carefully installed and sampled.

Groundwater Monitoring and Corrective Action

The groundwater monitoring and corrective action requirements of RCRA Subtitle D have three steps: detection monitoring, assessment monitoring, and corrective action.

When contamination is detected, more extensive groundwater monitoring and possibly corrective action may be necessary.

Figure 9-14 shows a leaking landfill and one possible type of corrective action. All landfills that are required to monitor groundwater begin with detection monitoring.

Detection monitoring requires establishing background concentrations for a set of detection monitoring parameters. These indicator parameters include 47 volatile organic compounds (VOCs) and 15 metals. Unless a variance is given, these parameters must be sampled at least semi-annually during the active life of the facility and during closure and post-closure care periods.

If any of the constituents are detected at a statistically significant increase over background concentrations, assessment monitoring must begin within 90 days. Assessment monitoring may be avoided if it can be demonstrated that the increase was due to a source other than the landfill or an error in sampling, analysis, statistical evaluation, or natural variation in the groundwater.

Assessment monitoring continues until it is determined whether concentrations of contaminants exceed maximum levels under the Safe Drinking Water Act. Depending on the results, normal monitoring may resume or, if contamination levels warrant it, a program of remediation must begin. Such programs involve developing a remediation plan and often more extensive monitoring.

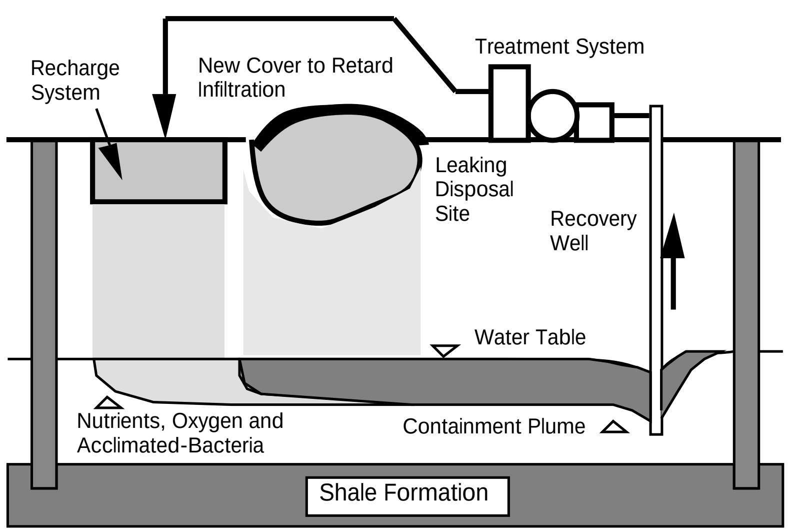
If contamination has migrated off-site, landowners and residents on land overlying the plume must be notified regarding the contamination and proposed corrective actions. Public hearings are required to evaluate the proposals.

The landfill owner may be required to implement the corrective actions and take interim measures such as the temporary supply of drinking water, if necessary. Corrective actions must continue until compliance with groundwater standards is achieved for three consecutive years.

The regulations for both groundwater monitoring and corrective actions are extensive and vary greatly among states. Individual state programs should be contacted to determine specific requirements.

Figure 9-14

Example of a Groundwater Remediation System



Source: Phil O'Leary, University of Wisconsin–Madison, Solid and Hazardous Waste Education Center, 1994

Gas Management

Uncontrolled landfill gas migration can be a major problem at a municipal solid waste landfill. The gas must be controlled to avoid explosions and vegetation damage in the vicinity of the landfill.

Because of the explosive quality of landfill gas, its migration must be monitored and limited.

RCRA Subtitle D standards limit the extent that landfill gas may migrate. Landfill gas concentrations may not exceed 25 percent of the lower explosive limit in occupied structures. This is equivalent to 1.25 percent methane in the building's atmosphere. The concentration of methane in the soil atmosphere can not exceed 100 percent of the lower explosive limit (5 percent methane) at the property line of the landfill site. Buildings at the landfill and monitoring probes located around the landfill must be tested quarterly each year for methane concentrations. Note that some states have more restrictive standards and require more frequent monitoring.

The composition of municipal landfill gas is controlled primarily by microbial processes and reactions in the refuse. Methane is usually the gas of concern. It is produced in about a 50:50 ratio with carbon dioxide. Other compounds are also produced and additional chemicals are released into the atmosphere by volatilization. Table 9-9 provides typical landfill gas composition. The oxygen and nitrogen levels shown are not products of decomposition; rather, they result from intrusion of air during gas sampling or analysis. On an air-free basis, and depending on the amount of dissolution of carbon dioxide and moisture in the landfill and the material being decomposed, the methane content typically ranges from 50 percent to 60 percent, the remainder being carbon dioxide and minor constituents as shown in Table 9-9.

Table 9-9

Typical Landfill Gas Composition

Component	Percent
Methane	47.4
Carbon dioxide	47.0
Nitrogen	3.7
Oxygen	0.8
Paraffin hydrocarbons	0.1
Aromatic-cyclic hydrocarbons	0.2
Hydrogen	0.1
Hydrogen sulfide	0.01
Carbon monoxide	0.1
Trace compounds	0.5

Source: Ham, R., USEPA, *Recovery Processing and Utilization of Gas from Sanitary Landfills*, 1979

Figure 9-15 gives typical amounts of landfill gas produced and recovered from a landfill; note the wide range in values. The total amount of gas generated in a full-sized landfill is difficult to determine because of the inherent uncertainty using isolated samples to predict total generation rates over long periods.

Landfills experience large variations in gas generation and recovery rates.

The gas that is generated will either vent to the atmosphere or migrate underground. In either case, monitoring and control equipment must be used to detect and control air pollution or damage to structures or vegetation. In addition to being a hydrocarbon source and greenhouse gas, landfill gas entering the atmosphere will carry with it trace quantities of a large number of volatile organic compounds, some of which have known detrimental health effects. Landfill gas traveling underground may enter structures, where explosive concentrations may build up, or it may displace oxygen, causing a danger of asphyxiation. Landfill gas in the soil profile may damage the vegetation on the surface of the landfill or on the land surrounding the landfill.

Why Gas Control is Needed

Methane can quickly asphyxiate a person, and concentrations as low as 5 percent are explosive. Methane displaces oxygen from the root zone and kills vegetation. Landfill operators must receive adequate safety training, and gas monitoring equipment and other safety devices must be properly calibrated and maintained.

When working near methane gas, safety is crucial.

If methane accumulates in a building it poses a severe hazard. Methane can enter a building through cracks, construction joints, subsurface utility openings, or weak spots in the basement wall or building floor. Because it is lighter than air, methane tends to accumulate near the ceiling. If the source of methane cannot be immediately controlled, the building must be evacuated or a methane alarm system must be installed and the building must be continuously vented. Following are some of the basic safety rules for dealing with methane:

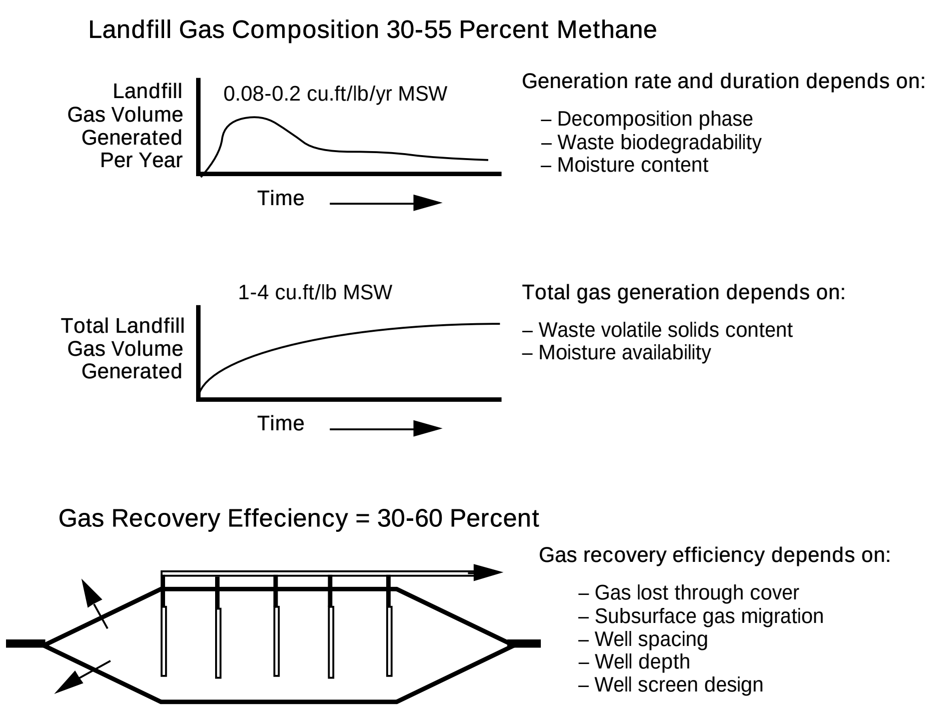
- Anyone entering a landfill vault or trench must check for methane gas, wear a safety harness, and have someone there to pull him or her to safety if needed.
- Anyone installing gas wells in a landfill must wear a safety rope to prevent falling into the borehole.
- Smoking must never be permitted while drilling or installing landfill gas wells or collection pipes, or when gas is venting.
- Gas collected from a mechanically evacuated system to minimize air pollution and reduce danger of explosion or fire must be flared.
- If it is suspected that methane gas has accumulated in a building, alert the fire department immediately. Most fire departments have equipment to detect methane and ventilate buildings.

The Mechanics of Gas Movement

Gas movement through refuse and soils is extremely complicated. The gas will tend to migrate from the landfill on a path through the refuse and surrounding soils that offers the least resistance. Gas will migrate farther through a highly permeable sand or gravel soil than it will through a less permeable

Figure 9-15

Factors Affecting Landfill Gas Generation and Recovery Rates



Source: P. O'Leary and P. Walsh, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course 1991-1992

silt or clay soil. The rate of migration will also be influenced by weather conditions. When barometric pressure is falling, gas will tend to be forced out of the landfill into the surrounding soil formations. Wet surface soil conditions and frozen ground may prevent gas from escaping into the atmosphere at the edge of the landfill; this may cause the gas to migrate even farther away from the landfill. Maximum migration distance of methane gas is difficult to predict. Migration distances greater than 1,000 feet have been observed.

Controlling Gas

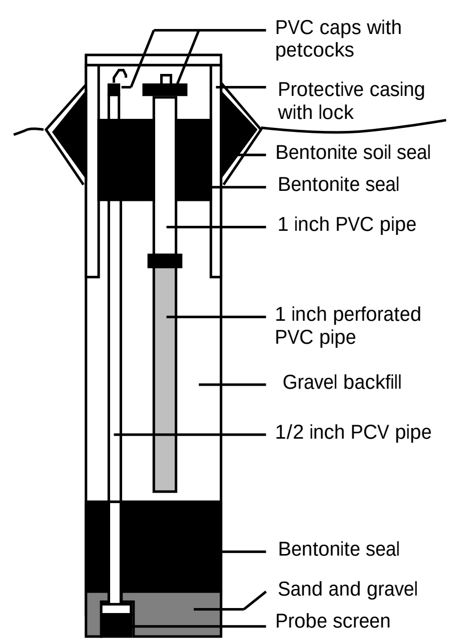
Controlling gas movement at a landfill begins with a study of the local soils, geology, and nearby area. For example, if the landfill is surrounded by a sand or gravel soil and if buildings are close to the landfill, the movement of gas into this area should be controlled by engineering methods. On the other hand, any landfill surrounded by clay may not require as stringent a control system. Note, however, that the clay cap installed at a completed landfill to exclude moisture infiltration and restrict leachate generation will, at the same time, tend to contain the landfill gas. The pressure gradient that results will force the gas to move laterally and into the areas surrounding the landfill. Even a narrow sand seam in a clay formation can transmit a large quantity of gas, especially if the gas cannot escape through the cover.

Gas Probes

Methane migration patterns and concentrations may change quickly.

Gas probes are used to detect the location and movement of methane gas in and around a landfill. A typical probe is shown in Figure 9-16. The probe is installed by boring a hole into the landfill or the ground around it. If off-site migration is a concern, the hole should extend at least 150 percent of the depth of the landfill, but not below the water table. A pipe with a perforated zone at the bottom is placed into the hole and the space between the original soil and pipe is filled with sand or gravel over the perforated portion. A bentonite slurry or other impermeable material is packed around the pipe above the perforated interval to the ground surface to prevent air leaking into the probe. At some sites, multilevel probes are installed to obtain a more accurate three-dimensional picture of gas movement.

Figure 9-16
Example of a Gas Monitoring Probe



Source: UW–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1991-1992

Two types of measurements are conducted. Gas pressure is measured with a gauge or manometer. Gas pressure gradients indicate landfill gas movement. The concentration of methane is also measured by using a calibrated meter on site or by taking samples for laboratory analysis.

Since the migration patterns and the methane concentrations change rapidly, frequent measurements are required to obtain an accurate picture of the gas migration pattern. At sites where there is much concern about gas migration endangering residences, daily measurements should be conducted until migration controls are put into place.

Gas Control Systems

Passive Gas Control Systems

Passive vents are sometimes used to control landfill gas migration. Passive systems rely on natural pressure and convection mechanisms to vent the landfill gas to the atmosphere. Figure 9-17 shows typical arrangements for gas venting. Recent research findings (Lofy, 1992) and field observations have confirmed that passive systems offer only limited protection. In areas where there is a significant risk of methane accumulating in buildings, passive systems may not be reliable enough to be the sole means of protection. Because of the unpredictability of gas movement in landfills, the use of passive venting is declining in modern landfill designs. Active systems are becoming more common.

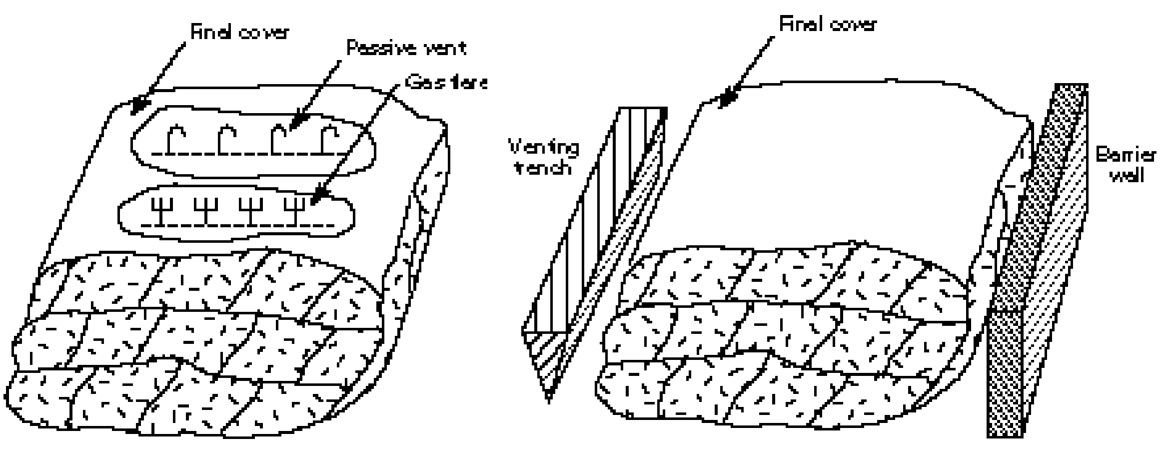
Active Gas Collection Systems

Active gas collection is more reliable than passive venting.

Active gas collection systems remove the landfill gas with a vacuum pump from the landfill or the surrounding soils. These systems may provide migration control or recover methane for use as energy. In both cases, gas recovery wells or trenches and vacuum pumps are employed. A pipe network is built to interconnect wells and blower equipment. When the primary purpose is migration control, recovery wells are constructed near the perimeter of the landfill. Depending on site conditions, the wells may be placed in the waste or in the surrounding soils, if they are reasonably permeable, as shown in Figure 9-18.

At landfills where the waste has been placed up to the property line, there may not be sufficient space to put wells and collection lines outside the waste. In such cases, interior wells, especially near the waste-soil boundary, are used.

Figure 9-17
Typical Arrangements for Passive Gas Venting



(Note: Passive vents provide limited protection. See text.)

Source: P. O'Leary and P. Walsh, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course 1991-1992

Borehole diameters for an active gas well are generally one to three feet. Larger diameter holes provide more surface area at the refuse-gravel interface, require less suction for gas removal, and are less prone to plugging. They are used if large amounts of gas are expected from each well, as in the case of gas recovery.

Collecting Gas for Beneficial Use

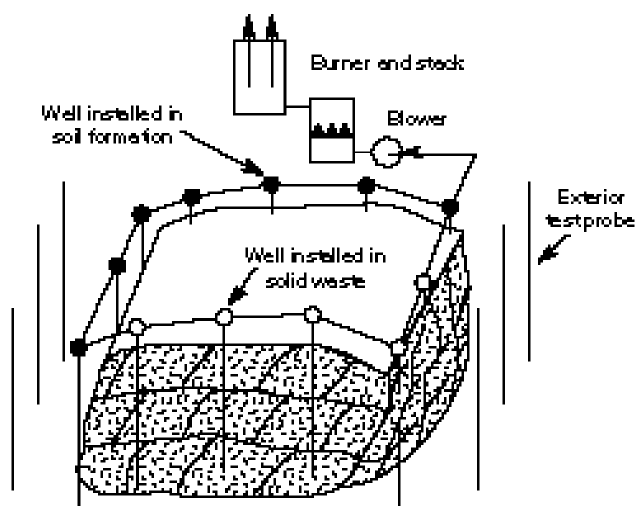
At some landfills, it is cost-effective to install gas recovery wells or trenches throughout the landfill and recover the gas for its energy value. In addition to the wells that may be constructed along the landfill's perimeter for migration control, wells or trenches may be placed in a grid pattern throughout the landfill to recover gas that might otherwise escape through the landfill cover. Depending on gas quality and user requirements, gas collected along the perimeter may be flared so as not to dilute the higher-quality gas typically collected from interior wells or trenches.

Wells are connected to a collection system that carries the gas to energy recovery equipment, as shown in Figure 9-19. Pipes connecting wells or trenches are called laterals or headers. The overall design must take settlement into consideration and should be sloped to drain gas condensate. The piping material must resist corrosion.

Collected landfill gas can be directly vented to the atmosphere in some locations, burned or flared, or directed to an energy recovery system. Venting is usually done through a stack, to provide atmospheric dispersion and to minimize the potential of odor problems. If odor problems or the presence of undesirable air contaminants justify it, the gas may be directed through a burner for combustion. If the methane concentration exceeds 15 percent and will support a flame, a supplemental fuel (such as natural gas) is not needed. This is important because supplemental fuel can greatly increase the operating cost of the landfill gas control system. When the methane gas concentration is greater than approximately 35 percent, it may be worthwhile to recover the energy from the gas. Landfill gas containing 47 percent methane has a heating value of 476 Btu / standard cubic foot; this compares to 1,030 Btu for natural gas.

Figure 9-18

Active Gas Control Systems



Source: P. O'Leary and P. Walsh, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course 1991-1992

Before constructing an energy recovery system, it is important to conduct tests to predict the quantity and quality of gas available. Testing is important because wide variations have been observed in gas generation rates and compositions. A pumping test is conducted by installing a gas recovery well and a number of monitoring probes in the landfill. The well is pumped until the gas flow stabilizes. Chemical characterizations of the gas are measured to determine methane content and the concentration of other chemicals; concurrently, the probes are monitored for pressure drop and methane content. The probes help define the volume of the landfill influenced by a well.

Methods of Energy Recovery

Landfill gas may contain sufficient methane to be an energy source.

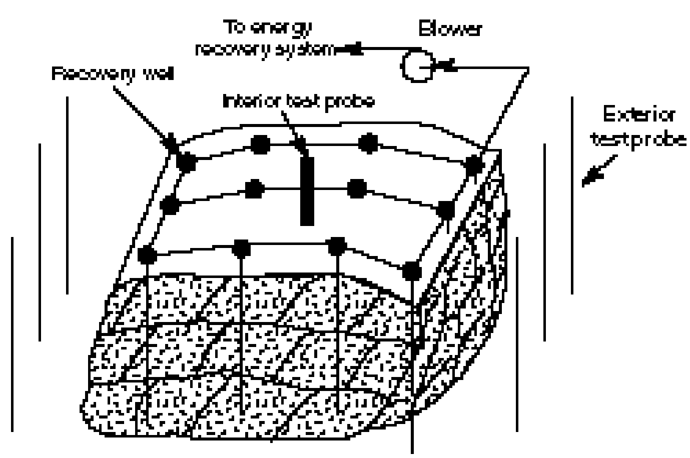
The method of energy recovery depends primarily on the available energy markets. If a factory or large building is near the landfill, it may be practical to pipe the gas directly into a boiler at the facility. The landfill gas typically is passed through condensate knock-out tanks designed to remove liquid droplets by a baffle system and then injected into the furnace in combination with the regular boiler fuel, which may be coal, oil, or natural gas. A blower is needed to pull gas from the landfill and transport it at the desired pressure to the user. Using landfill gas as supplementary boiler fuel is possibly the simplest approach, but a suitable boiler is seldom available near a landfill. If the gas must be transported, the cost of a pipeline between the site and the boiler must be compared to the value of the gas.

Electricity and pipeline quality gas can be produced from landfilling gas.

Often a boiler is not available as a feasible market for the methane gas. In this case, landfill gas can be directed to an engine / generator system for producing electricity. Almost all landfills have electrical service and the generated power can be used on site or sold to the electric grid. To produce electricity, the gas is compressed, dewatered, and possibly purged of particulates before it is used as a fuel in an internal combustion engine or a gas turbine.

Since the methane content of the gas will directly affect the performance of the engine or turbine, the site operator must closely regulate the gas collection system. The cost-effectiveness of generating electricity from landfill gas is limited by the price paid for the electricity by the utility and varies widely, depending on local power costs and generating capacity.

Figure 9-19
Gas Collection Systems with Wells



Source: P. O'Leary and P. Walsh, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course 1991-1992

Natural gas pipelines are located near many landfill sites. Several different methods including membranes, liquid solvent extraction, molecular sieves, and activated carbon adsorption, have been used to remove the carbon dioxide and other noncombustible constituents from methane landfill gas. The gas is thereby upgraded to pipeline quality and injected into the natural gas distribution network. The landfill operator is paid by the natural gas utility for the value of the methane. The market for such gas is generally excellent, but the cost of upgrading the gas to meet pipeline specifications presents problems. Generally, such gas treatment is feasible only with larger landfills. Operation problems and economic costs have limited the extent to which this option has been implemented.

As gas emission control becomes more common for environmental and regulatory reasons, gas use will also probably become more common even if the income, for example, from electricity sales, is too low to justify the project on a financial basis alone. Although the energy available from landfill gas represents a small fraction of the total energy usage in the area, it can be important because it is available locally and continuously. Electricity and natural gas pipeline production from existing landfill gas recovery systems can often supply the electrical needs for 5,000 to 20,000 homes.

The USEPA has promulgated New Source Performance Standards and Emission Guidelines for landfills pursuant to mandates in the Clean Air Act. These rules will require landfills to collect landfill gas and prescribe design standards and performance limits for gas extraction systems.

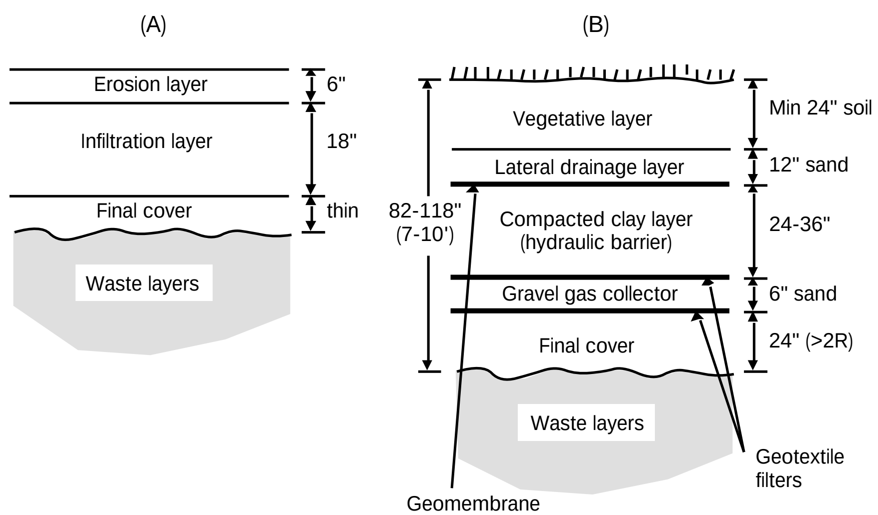
Final Cover System

RCRA Subtitle D specifies the type of final landfill cover.

To close an MSW Landfill, RCRA Subtitle D requires that the final cover system be composed of an infiltration layer that is a minimum of 18 inches thick and overlain by an erosion layer that is a minimum of 6 inches thick, as shown in Figure 9-20, drawing A. This requirement is applicable for existing, new, or lateral expansions of existing landfills. Figure 9-20, drawing B, shows a cover with additional layers incorporated into its design to promote lateral drainage of infiltration and to provide a zone under the cover for gas movement.

Figure 9-20

Examples of Final Covers



Source: J. Spear, 1994

As with other design features, states may have additional requirements.

Over the long term, the infiltration layer should minimize liquid infiltration into the waste. The infiltration layer must have a hydraulic conductivity less than or equal to any bottom liner or natural subsoils present to prevent a "bathtub" effect. In no case can the infiltration layer have a hydraulic conductivity greater than 1 x 10^{-5} cm / sec regardless of the permeability of underlying liners or natural subsoils. To meet the infiltration layer performance standard at a landfill with a flexible membrane bottom liner, it is likely that the final cover will also need to incorporate a flexible membrane liner. As with other design features, the state may have additional requirements.

Design Considerations

Design criteria for a final cover system should be selected to do the following:

- minimize infiltration of precipitation into the waste
- promote good surface drainage
- resist erosion
- prevent slope failure
- restrict landfill gas migration or enhance recovery
- separate waste from vectors (animals and insects)
- improve aesthetics
- minimize long-term maintenance
- otherwise protect human health and the environment.

The cover system should be designed to provide the desired level of long-term performance with minimal maintenance.

Reduction of infiltration in a well-designed final cover system is achieved through good surface drainage and runoff with minimal erosion, transpiration of water by plants in the vegetative cover and root zone, and restriction of percolation through earthen material. The cover system should be designed to provide the desired level of long-term performance with minimal maintenance. Surface water runoff should be properly controlled to prevent excessive erosion and soil loss. The vegetative cover should not contain deeply rooted plants that could damage the underlying infiltration layer. In addition, the cover system should be stable geotechnically to prevent failure, for example, sliding that may occur between the erosion and infiltration layers, within these layers, or within the waste.

Erosion Control

When designing the final cover system, it is common to use the universal soil loss equation or a similar model to predict erosion and aid in design. This helps specify the interrelationships between vegetation, slope, soil used, and climatic conditions. To minimize major erosion and post-closure care problems, the maximum slope is typically 4:1 (4 parts horizontal to 1 part vertical); however, 5:1 is better. A slope of 3:1 is likely to lead to long-term maintenance problems, but it may be feasible in some areas if the site is well maintained and the slope is not too long. Diversion channels consisting of berms or swales are used approximately every 200 feet to intercept runoff before it has a chance to accumulate and cut erosion gullies. Down spouts should be used to convey runoff down long, steep slopes.

Vegetation

Selection of vegetation is important in ensuring long-term, maintenance-free operation of the cover. Good vegetation will improve erosion control through rapid growth and the formation of a complex root system. Vegetation commonly used includes vetches and fescues; however, it is a good idea to check with the local highway department for suggestions regarding vegetation for erosion control in the climate at hand. Table 9-10 describes recommendations for establishing vegetation on a landfill cover.

Other Design Considerations

In addition to the major issues of gas and leachate control and final cover, many other elements of landfill design require attention.

Roads

Each design element is important to the long-term success of the landfill.

Traffic control and roads are important. On-site routing of trucks to the working face should be planned to minimize waiting times at the site. A permanent road from the public road system to the site should be provided. The road should be 15 feet wide for small operations and 20 to 24 feet wide for larger landfills. Grades should not exceed 7 percent uphill and 10 percent downhill for loaded vehicles (Sittig, 1979).

Special working areas should be designated on the site plan for inclement weather or other contingency situations. Access roads to these areas should be of all-weather construction.

Table 9-10
Steps for Planting and Maintaining Vegetation on Landfills

1. Select an end use.
2. Determine depth of cover.
   Cover soil must be at least 60 cm deep for grass establishment and 90 cm for shrubs and deeper for trees.
3. Establish an erosion control program.
   The soil on recently covered landfills must be stabilized soon after spreading to prevent erosion.
4. Determine the soil nutrient status.
   Before or during the grass and ground cover experiments, soil tests should be made for pH, major nutrients (nitrogen, potassium, and phosphorus), conductivity, bulk density, and organic matter.
5. Determine soil bulk density.
   Cover soil is frequently compacted by landfill equipment during spreading operations to bulk densities that will severely restrict plant root growth.
6. Amend soil cover.
   The soil over the entire planting area should be amended with lime, fertilizer, and/or organic matter according to soils tests before planting. These materials should be incorporated into the top 15 cm of soil.
7. Select landfill-tolerant species.
   Grasses and other ground covers can be selected for planting in the soil cover by evaluating the results of the experimental plots established earlier to determine landfill-tolerant species.
8. Plant grass and ground covers.
   It is generally desirable to embed the seed in the soil. Mulches can be used as an alternative to embedding the seed but is less likely to be effective.
9. Develop the tree and shrub growth.
   Trees and shrubs should not be planted for 1 or 2 years after grass has been planted. If the grass cannot grow because of gases from the landfill, other deeper-rooted species are not likely to thrive either.

Source: Adapted from Gilman, et al., *Standardized Procedures for Planting Vegetation on Completed Sanitary Landfills,* 1983

Hauling routes to the site should use major highways as much as possible. Potential routes should be studied to determine the physical adequacy of roadways for truck traffic, as the landfill may cause a significant increase in truck traffic on nearby roads. Local authorities may require that the roads be improved to handle the higher traffic counts and heavier vehicles.

Storm Water Drainage

RCRA Subtitle D further specifies run-on and runoff controls for controlling drainage into and out of the landfill working face.

Runoff from rainfall and snow melt must be planned for by developing drainage channels within the site. Sloped areas within the landfill will cause larger volumes and higher peak runoff flows from the site than would occur naturally. The runoff should be directed into channels that are capable of carrying most storm loads without overflowing or flooding adjacent areas. Generally, drainage structures are designed for 25-year storms. RCRA Subtitle D further specifies run-on and runoff controls for controlling drainage into and out of the landfill working face.

To minimize siltation problems downstream, a detention basin should be considered. Runoff directed into the basin is released at a slow rate after most sediment has settled to the bottom of the basin. This arrangement also provides an opportunity to test runoff water for chemical contamination before it is discharged to a stream or lake.

Utilities

The landfill will need electrical service for buildings, pumps, and blowers. A source of water for the employees must be provided for sanitary and possibly shower facilities. If a public water supply utility is located nearby, a supply line can be connected to the service building. A water supply well can be drilled in rural areas, but regulations may specify a setback distance between a landfill and a well; in such cases, the well may be located far away from the service building.

Scales

Most large landfills are equipped with scales for weighing incoming loads. Charges to users can be prepared from the weight records. The filling rate and compaction density can be more accurately monitored with scales than with truck counts and gate volume estimates.

A building will be needed for a scale attendant. Note that although the weighing system can be fully automated, a full-time attendant is needed to monitor waste sources. The service building for equipment maintenance and for employee headquarters may also be at this location.

Regulatory Approvals

Achieving regulatory approval is the culmination of a long-term effort that begins early in the development process. Chapter 1, on public education, and Chapter 2, on siting, should be consulted for suggested approaches to facilitate public participation. Projects lacking public review or input until the design is completed may face substantial delays in the approval process. The final task in developing the plan is to obtain approval from regulatory agencies. The designer should maintain a close liaison with regulatory people throughout the design process to ensure compliance with regulatory standards.

Several different agencies usually must issue approvals.

After submitting applications and plans, the agency reviewing the proposal may have additional questions to be answered by the developer. Additional permits may be needed from local agencies, state agencies other than the one dealing specifically with landfills, and federal agencies, such as the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

Many states have a requirement mandating preparation of an environmental impact statement. The purpose of the environmental impact statement is to disclose the nature of the proposed project, assess current and possible future environmental conditions, and to describe alternatives to the proposed action.

OPERATING THE LANDFILL

Documented operating procedures can be crucial if questions arise in the future regarding the adequacy of site construction.

The landfill operational plan should serve as the primary resource document for operating the site. It shows the technical details of the landfill and the procedures for constructing the various engineered elements.

Since a landfill is constructed and operated over a number of years, it is important that personnel periodically review the plan and refresh their memories to ensure conformance with the plan over the long term. If operating procedures must be modified, the changes must be noted so that an accurate record is maintained. Documented operating procedures can be crucial if questions arise in the future regarding the adequacy of site construction.

After receiving the required approvals for the site design, preparation and construction of the site can begin. Table 9-11 provides site preparation and construction tips.

Table 9-11
Site Preparation and Construction Steps

1. Clear site.
2. Remove and stockpile topsoil.
3. Construct berms.
4. Install drainage improvements.
5. Excavate fill areas.
6. Stockpile daily cover materials.
7. Install environmental protection facilities (as needed).
    - landfill liner with leachate collection system
    - groundwater monitoring system
    - gas control equipment
    - gas monitoring equipment
8. Prepare access roads.
9. Construct support facilities.
    - service building
    - employee facilities
    - weigh scale
    - fueling facilities
10. Install utilities.
    - electricity
    - water
    - sewage
    - telephone
11. Construct fencing.
    - perimeter
    - entrance
    - gate and entrance sign
    - litter control
12. Prepare construction documents. (continuously during construction)

Source: P. O'Leary and P. Walsh, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course 1991-1992

Providing Financial Assurance

Before opening a landfill, the owner and operator must provide financial assurance for closure and 30-year post-closure care. Refer to the section later in this chapter on financial assurance for more detailed information.

Program to Detect and Exclude Hazardous Waste

The owner or operator is required to implement a program to detect and exclude regulated hazardous wastes and PCBs from disposal in the landfill. This program must include the following elements:

- performing random inspections of incoming loads or other prevention methods

- maintaining inspection records
- training facility personnel
- notifying appropriate authorities if hazardous wastes or PCB wastes are detected.

Inspections

Random inspections of incoming loads are required.

An inspection is typically a visual observation of the incoming waste loads by an individual who is trained and qualified to identify regulated quantities of hazardous waste or PCB wastes that would not be acceptable for disposal at an MSW landfill. An inspection is considered satisfactory if the inspector knows the nature of all materials received in the load and is able to discern whether the materials are potentially regulated hazardous wastes.

Random inspections provide a reasonable means to adequately control the receipt of inappropriate wastes. The frequency of random inspections may be based on the type and quantity of wastes received daily, and the accuracy and confidence desired in conclusions drawn from inspection observations. Since statistical parameters are not provided in the regulation, a reasoned, knowledge-based approach may be taken. A random inspection program may take many forms, such as inspecting every incoming load one day out of every month or inspecting one or more loads from transporters of wastes of unidentifiable nature each day.

Inspection frequency also can vary depending on the nature of the waste. For example, wastes received exclusively from commercial or industrial sources may require more frequent inspections than wastes collected exclusively from households. Priority can also be given to inspecting haulers with unknown service areas, to loads brought to the facility in vehicles not typically used for disposal of municipal solid waste, and loads transported by known previous offenders.

To provide the facility owner or operator the opportunity to refuse or accept wastes, loads should be inspected before actual disposal of the waste at the working face of the landfill. Inspections can be conducted on a tipping floor of a transfer station before transferring the waste to the disposal facility. Inspections may also occur at a tipping floor located near the facility scale house, inside the site entrance, or near, or adjacent to, the working face of the landfill.

Alternative Methods for Detection and Prevention

While the regulations explicitly refer to inspections as an acceptable means of detecting regulated hazardous wastes and PCB wastes, preventing the disposal of these wastes may be accomplished through other methods. These methods may include receipt of household wastes and processed (shredded or baled) wastes that are screened for the presence of the excluded wastes before processing.

Cover Material Requirements

RCRA Subtitle D standards require the owner or operator to cover solid waste with six inches of an earthen material at the end of each operating day.

RCRA Subtitle D standards require the owner or operator to cover solid waste with six inches of an earthen material at the end of each operating day. Six inches of cover will prevent exposing the waste to birds, insects, and rodents, which represent the principal transmission pathways of human disease. Cover material also reduces the exposure of combustible materials to ignition sources, reduces odors, and controls blowing litter. Removing the waste from sight also reduces scavenging. The use of alternative material of alternative thicknesses for daily cover may be allowed in certain jurisdictions.

Air Criteria

RCRA Subtitle D standards prohibit routine open burning of solid wastes. Infrequent burning of agricultural and silvicultural waste, diseased trees, or debris from land clearing or emergency cleanup operations is allowed subject to state and federal air pollution control regulations. Any burning area should be far enough from the landfill to avoid burning other solid waste.

The USEPA has promulgated New Source Performance Standards and Emission Guidelines for landfills pursuant to mandates in the Clean Air Act. These rules will require landfills to collect landfill gas and prescribe design standards and performance limits for gas extraction systems.

Access Control

Public access to landfills must be controlled by use of artificial barriers, natural barriers, or both to prevent unauthorized vehicular traffic and illegal dumping of wastes. These barriers can include fences, ditches, berms, trees, etc. Access should be controlled by gates that can be locked when the site is unsupervised.

Run-on and Runoff Control Systems

Site drainage is always critical in a good sanitary landfill design.

Site drainage is always critical in a good sanitary landfill design. As much water as possible should be diverted off the landfill to minimize operational problems and the formation of leachate.

Landfill operators are required to have a run-on control system to prevent flow onto the active portion of the landfill during the peak discharge from a 25-year storm event. The goal of the run-on system is to collect and redirect surface waters entering the landfill boundaries.

A runoff control system from the active portion of the landfill must be able to control at least the volume of water that results from a 24-hour, 25-year storm. The runoff control system should be designed to collect and control any water that may have contacted any waste materials. The runoff must be managed in compliance with the point and nonpoint source requirements of the Clean Water Act.

Small Vehicles and Safety

Many landfill operators find that allowing public access at the disposal face interferes with site operation and can lead to unsafe conditions. Separate waste collection facilities such as 40-cubic-yard containers can be located near the site entrance for private citizens. Such facilities provide disposal service to the public, while eliminating possible interference with operations. On a regular basis, the area should be inspected and litter picked up to prevent unsightly conditions.

Additional Controls

Good housekeeping procedures are necessary for landfill operations. RCRA Subtitle D requirements and many state regulations mandate controls on operation. For details regarding the regulations, see 40 CFR Part 258 and the appropriate state regulations. A well-planned and maintained landfill effectively controls for the following:

- **Aesthetics:** Although making the site pleasing to look at is cosmetic, it is not frivolous. Addressing aesthetic concerns may include using fences, berms, plantings, or other landscaping to screen the landfill's daily operations from roads or nearby residents, and providing an attractive entrance with good roads and easy-to-read signs.
- **Wind-Blown Paper:** On-site litter control is accomplished by using fences to stop blowing paper and plastic. Frequent manual or mechanical litter pick up is also needed.
- **Insects:** Flies and mosquitoes are the most common insects of concern to neighbors. They are best controlled by covering the solid waste daily

and eliminating any open standing water, such as in appliances stored for recycling or in surface depressions.

- **Rodents and Wildlife:** Rats were once a problem at open dumps, but at sanitary landfills, burying all food wastes with daily cover material usually eliminates rat problems.
- **Birds:** Birds can be a nuisance or even cause problems with planes if the landfill is near an airport. Federal Aviation Administration (FAA) should be notified if the landfill is within five miles of an airport runway used by jet aircraft. Methods to discourage birds include use of noise makers, wire grids, and liberal use of cover soil. The best approach is to keep the working face small and to provide adequate cover.

The landfill operator must be trained and equipped to handle a wide variety of conditions and situations.

- **Odors and Fires:** Odors are best controlled by daily cover, as well as by adequate compaction. Daily cover also forms cells that reduce the ability of inadvertent fires to spread throughout the landfill. Any burning or smoking waste should be dumped off to the side and extinguished before placing it in the working face. Fire-fighting equipment and an emergency water supply should be available on site or arranged for with local authorities.
- **Noise:** Equipment should be operated behind berms, which shield the surrounding area from noise as much as possible. Access should be designed to minimize the impact that landfill site traffic has on nearby neighborhoods.
- **Dust and Tracking:** Roads should be watered in dry periods to keep dust to a minimum. Roads should be crowned and well-drained to minimize mud tracking. Adequate wheel-cleaning and mud knock-off areas should be provided. Entrance roads should be paved or have all-weather surface concrete or asphalt to keep mud tracking on-site and should be cleaned whenever a mud buildup occurs.
- **Scavenging:** While recycling at a landfill may be desirable, scavenging (or uncontrolled picking through waste to recover useful items) is not desirable. Because scavengers have been injured, sometimes fatally, while picking through the wastes, the practice should be prohibited. Salvaging, which is the controlled separation of recoverable items, should be distinguished from scavenging. Any salvage operations should be kept away from the landfill, usually at the gate area, and residues should not be allowed to accumulate.
- **Gas and Leachate:** Particularly important to the protection of public health and the environment is the control of gas generated by the decomposition of solid wastes, and of leachates that form as water migrates through the solid wastes. Because of their importance, methods to control both gas and leachate were considered in earlier sections of this chapter.

Landfill Equipment

Equipment at sanitary landfills falls into three functional categories: waste movement and compaction, earth cover transport and compaction, and support functions. Selection of type, size, quantity, and combination of machines required to move, spread, compact, and cover waste depend on the following factors (ASCE, 1976):

- amount and type of waste to be handled
- amount and type of soil cover to be handled
- the distance the cover material must be transported
- weather conditions
- compaction requirements

- site and soil conditions: topography, soil moisture, and difficulty of excavation
- supplemental tasks such as maintaining roads, assisting in vehicle unloading, and moving other materials and equipment around the site.

Many factors must be considered when selecting landfilling equipment.

The amount of waste is the major variable influencing the selection of an appropriate-size machine. Table 9-12 shows equipment needs. Heavier equipment provides more compaction, all else being equal, but also provides more flexibility in handling and compacting a variety of materials using thicker compaction lifts. The condition in which the waste is received may affect choice of equipment. For example, landfills accepting only shredded wastes are operated much like landfills handling unprocessed wastes, although there may be less need for daily soil cover, and it will be easier to compact the waste. For landfills handling baled waste, the bales are often moved with forklifts and no compaction equipment is needed.

Table 9-12
Equipment Needs by Daily Tonnage

Approximate Population	Daily Wastes Tons	Equipment Number	Equipment Type	Equipment weight, lbs	Accessory[a]
0-20,000	0-50	1	Tractor, crawler	10,000-30,000	Dozer blade Front-end loader (1-2 cu/yd) Trash blade
20,000-50,000	50-150	1	Tractor, crawler	30,000-60,000	Dozer blade Front-end loader (2-4 cu/yd) Bullclam Trash blade
		1	Scraper or dragline		
		1	Water truck		
50,000-100,000	150-300	1-2	Tractor, crawler	30,000+	Dozer blade Front-end loader (2-5 cu/yd) Bullclam Trash blade
		1	Scraper or dragline[b]		
		1	Water truck		
>100,000	300[c]	1-2	Tractor, crawler	45,000+	Dozer blade Front-end loader (2-5 cu/yd) Bullclam Trash blade
		1	Steel wheel compactor		
		1	Scraper or dragline[b]		
		1	Water truck		
		—[a]	Road grader		

a. Optional, depends on individual needs.
b. The choice between a scraper or dragline will depend on local conditions.
c. For each 500-ton increase add one more of each piece of equipment.

Source: G. Tchobanoglous, *Integrated Solid Waste Management: Engineering Principles and Management Issues, 1993*

The degree of compaction is critical to extending the useful lifetime of a landfill. For achieving high, in-place waste densities, a compactor may be necessary. A minimum in-place compaction density of 1,000 pounds per cubic yard is recommended. The number of passes that the machine should make over the wastes to achieve optimum compaction depends upon machine wheel pressure, waste compressibility, and compaction layer thickness. In general, three to five passes are recommended to achieve optimum in-place waste densities, as shown in Figure 9-21. Although additional passes will compact the waste to a greater extent, the return on the effort diminishes beyond six passes.

Figure 9-21 also shows the relationship between the waste layer thickness for compaction and the compacted waste density found in a field test for a particular type of machine and operating procedure. Each landfill will have different results, but the shape of the curves will be similar. Note the rapid decrease in density above a compacted layer thickness of about 1-1/2 feet. Thus, the best solid waste compaction results from compacting the waste in layers one to two feet thick.

The working face slope will affect the degree of compaction achieved. As the slope increases, vertical compaction pressure decreases. The highest degree of compaction is achieved with the least slope. However, the feasibility of a nearly flat working face grade has to be weighed against the larger area over which the solid wastes and cover soil must be spread.

Waste Handling and Compaction

There are several factors to consider when making decisions about waste handling and compaction, shredding and baling of wastes, and the types of equipment used for compacting the wastes.

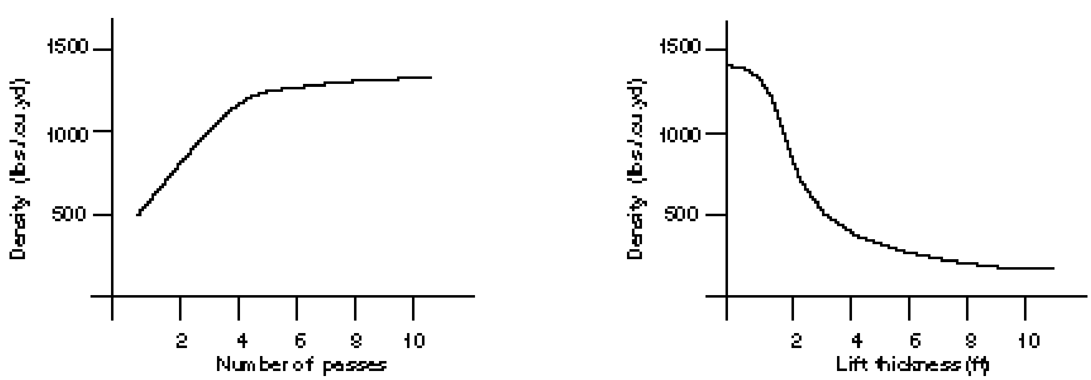
Shredding and baling are options for processing waste before it is landfilled.

Waste Shredding

In shredding of solid waste, incoming refuse is mechanically processed into small uniformly sized pieces. Shredding can take place immediately before landfilling or it can be done at a transfer facility prior to transport. While shredding may be undertaken as the sole processing technique used before disposal, it also can be one step in a process that includes the mechanical separation and removal of recyclable or reusable materials from the waste stream.

After compaction, shredded refuse has a greater density than compacted, unprocessed MSW. This can result in preserving landfill space and reducing

Figure 9-21
Waste Densities



Source: P. O'Leary and P. Walsh, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course 1991-1992

The benefits of waste shredding must be evaluated with several other factors in mind.

the amount of required cover material. In addition, landfill settlement and stabilization may be more uniform over time in the landfilled area. These benefits must be compared with the significant capital and operating costs of the shredding equipment, the space required to process the waste, and the historically significant potential for worker injury and equipment downtime caused by explosions from crushing compressed gas containers and by the ignition of explosive gases by sparking metal.

Baling Solid Waste

The baling of municipal solid waste involves the compaction of refuse into high-density blocks that are stacked and covered with cover material in a landfill. Depending on the equipment used, the bales can have a density between 1,000 to 1,900 pounds per cubic yard. In certain circumstances, baling municipal solid waste before disposal may result in landfill space savings as a result of increased compaction density and reduced cover material requirements. Baling wastes can also reduce the amount of blowing litter.

Landfill Handling and Compaction Equipment

Steel-wheeled compactors are designed specifically for compacting solid wastes. Wheels are studded with load concentrators of various designs. This equipment gives maximum compaction of solid wastes. Steel-wheeled compactors are best suited to medium or large sanitary landfills, which can support more than one machine, since these units are suitable only for compaction work.

Track-type tractors or dozers may be used for handling and compacting waste, as well as for cover excavation and compaction. Such units can also be used for site preparation, road construction, and maintenance. These are the most versatile units and are preferred for small operations in which one unit must perform a variety of functions.

Earth Movers

Rubber-tired loaders or dozers provide more speed and maneuverability than track-type units and can haul cover efficiently and apply it up to approximately 1,000 feet from the working face. Rubber-tired scrapers are efficient for excavating and transporting soil for cover when it is more than 1,000 feet from the working face. Where the soil is hard to excavate (e.g., clay or frozen soil), scrapers can be pushed with a bulldozer.

Draglines are also efficient earth movers but are only able to deposit soil within the area reached by the boom and are not suitable for transporting cover material. Backhoes are well suited for small, specialized excavation at the landfill, such as for a leachate collection system. Dump trucks can be used at landfills in conjunction with excavation equipment for moving cover material. Motor graders are useful for road construction and maintenance, for construction of berms and drainage ways, and for landscaping.

Equipment Maintenance and Backup

Proper maintenance of landfill equipment is important.

Equipment maintenance is clearly an important task. Regular maintenance reduces breakdowns and identifies equipment problems early, before more costly and time-consuming repairs are needed. Provision must also be made for backup equipment, perhaps by keeping additional equipment available.

Adverse Weather

Wet weather problems are especially serious with soils that have a high silt or clay content. When wet, these soils usually become muddy and slippery. Provision should be made to continue operating areas less susceptible to such problems. Procedures to minimize and clean mud tracking on roads are especially important during wet weather.

Cold weather brings many problems in starting and operating machinery, keeping employees comfortable, and obtaining cover material. Equipment manufacturers can offer recommendations for cold weather starting and operation, and excavation of well-drained and stockpiled cover soil can improve cold weather operations.

Windy conditions can require the use of extra or specially placed fencing and use of a lower or more protected working face. Unloading wastes at the bottom of the working face can help because the wind cannot pick up materials as easily as when wastes are deposited at the top of the working face.

Fencing and the area downwind of the working face should be cleaned at least daily.

In addition to fencing at the perimeter of the active area, portable fences are often used to catch litter immediately downwind of the working face. Fencing and the area downwind of the working face should be cleaned at least daily.

Dust can be a nuisance at landfills, both to employees and to neighbors. Water wagons can be used to control dust. Calcium chloride is also used for dust control, because it absorbs moisture from the air.

Personnel and Safety

To maintain an efficient landfill operation, employees must be carefully selected, trained, and supervised. Proper landfill operation depends on good employees. Along with equipment operators, other necessary employees may include maintenance personnel, a scale operator, laborers, and a supervisor. People will also be needed to keep financial and operating records. Good employee training and supervision must include attention to safety. Operating a landfill presents many challenges; accidents are expensive and have hidden costs often several times the readily apparent costs.

Solid waste personnel work in all types of weather, with many types of heavy equipment, with a variety of materials presenting diverse hazards, and in many different types of settings. The types of accidents possible at landfills include injury from explosion or fire, inhalation of contaminants and dust, asphyxiation from poorly vented leachate collection system manholes or tanks, falls from vehicles, injury associated with operating heavy earth-moving equipment, injury from attempting to repair equipment while engines are operating, exposure to extreme cold or heat, and traffic accidents at or near the site.

Safety guidelines specific to the operation of landfill equipment are shown in Table 9-13. Educational films and written material on safety at the landfill are available from the federal government and from equipment manufacturers. Assistance in setting up a safety program is available from insurance companies with worker's compensation programs, the National Safety Council, safety consultants, and federal and state safety programs.

Table 9-13

Safety Suggestions for Sanitary Landfill Equipment Operators

- Check equipment before starting.
- Use steps and hand holds.
- Keep steps clean.
- Inspect area before moving.
- Operate from driver's seat.
- Wear seat belts.
- Never mount moving equipment.
- Authorized passengers only.
- Keep bucket or blade low.
- Check blind areas.
- Keep enough clearance.
- Avoid side-of-hill travel.
- Avoid excessive speed.
- Do not crush sealed containers.
- Go carefully over bulky items.
- Check work area.
- Park on level ground.
- Lower attachments to ground when parked.
- Never jump from equipment.
- Avoid leaving equipment unattended.
- Always have adequate lighting.
- Clean equipment before repairing.
- Remain in seat during equipment adjustments.

Source: P. O'Leary and P. Walsh, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course 1991-1992

Quality Control and Record Keeping

During all construction, a quality control program should be followed to ensure the landfill conforms to the design and operating plans. An inspector should be on site to approve construction work as each structure or construction sequence is completed. Compliance with specifications should be checked by soil tests before waste is placed over the liner. Grades and elevations can be measured with surveying equipment to document the as-built features of the landfill.

RCRA Subtitle D requirements and many state regulations establish record-keeping requirements.

RCRA Subtitle D requirements and many state regulations establish record-keeping requirements. For details regarding the regulations, see 40 CFR Part 258 and the appropriate state regulations.

Operational records that should be maintained include waste quantity by tons or, preferably, by volume (since landfill capacity is by volume), cover material used and available, equipment operation and maintenance statistics, and environmental monitoring data. Data on waste loadings will allow the site operator to predict the useful, remaining site life; any special equipment that may be needed; or personnel requirements. Financial records are also crucial for maintaining sound operations. To ensure and document adherence to the design and operating plans, many sites now have engineers or certification personnel always on hand, or at least during major construction and periodically thereafter.

Community Relations

An important and often overlooked aspect of landfill operation is sustaining good community relations. The landfill manager must maintain a dialog with neighbors, municipal leaders, community activists, and state governmental representatives in an effort to build trust through honest communications. While community relations activities do not guarantee continued support for the landfilling operation, poor relations almost certainly will result in complaints and problems.

CLOSING THE LANDFILL AND PROVIDING POST-CLOSURE CARE

The landfill must be closed in accordance with an approved closure plan. The goal of closure and post-closure care is to ensure the long-term protection of human health and the environment. The owner or operator must close the landfill in a manner that will minimize the need for maintenance and will be protective of human health and the environment.

Financial Assurance for Closure and Post-Closure Care

Federal standards require that landfill owners and operators, including municipalities that operate landfills, have financial assurances in place to cover the costs of closure and post-closure. Financial assurance is also required when corrective action is necessary to clean up releases of hazardous constituents to groundwater. Several mechanisms are allowed, including trust funds, surety bonds, letters of credit, insurance, a state / tribal approved mechanism, state / tribal assumption of responsibility, and use of multiple mechanisms. USEPA will issue a rule that would allow a local government financial test.

Design and operating procedures affect the cost estimates for financial assurance.

The closure and post-closure cost estimates used to determine the amount of coverage required must be based on the cost of closing the landfill at the point of the landfill's active life when the extent and manner of its operation would make closure and post-closure care the most expensive. Furthermore, cost estimates must reflect the costs that a third party would incur in conducting the closure and post-closure activities. The closure and post-closure cost estimates must be updated yearly to account for inflation and updated whenever changes to the closure and post-closure plans or changes at the facility increase the cost of closure and post-closure. Whenever the cost estimates increase, the owner or operator must increase the level of financial assurance provided. Critical technical issues that must be faced by the designer include the following:

- the degree and rate of post-closure settlement and stresses imposed on soil liner components
- the long-term durability and survivability of cover system
- the long-term waste decomposition and management of landfill leachate and gases
- the environmental performance of the combined bottom liner and final cover system.

Procedures for Site Closure

The primary objectives of landfill closure are to establish low-maintenance cover systems and to design a final cover that minimizes the infiltration of precipitation into the waste. Installation of the final cover must be completed within six months of the last receipt of wastes.

Long-term maintenance and post-closure costs are important considerations when closing a site.

The procedures for placing the cover over the landfill are usually defined during site design. If no cover design is available, specifications must be prepared. See the section in this chapter on cover design for more information. Table 9-14 shows the procedures to follow when either the entire landfill or a phase of it has been filled to capacity. Phased closure is recommended. Construction techniques ensuring that quality closure is achieved, especially with regard to final cover and vegetation, will minimize long-term upkeep problems. After cover placement, the area should be immediately planted with vegetation to prevent erosion.

Table 9-14

Procedures for Site Closure

Preplanning:

- Identify final site topographic plan.
- Prepare site drainage plan.
- Prepare vegetative cover and landscaping plan.
- Identify closing sequence for phased operations.
- Specify engineering procedures for the development of on-site structures.

Three Months Before Closure:

- Review closure plan for completeness.
- Schedule closing date.
- Prepare final timetable for closing procedures.
- Notify appropriate regulatory agencies.
- Notify site users by letter if they are municipalities or contract haulers; by published announcements if private dumping is allowed.

At Closure:

- Erect fences or appropriate structures to limit access.
- Post signs indicating site closure and alternative disposal sites.
- Collect any litter or debris and place in final cell for covering.
- Place cover over any exposed waste.

Three Months After Closure:

- Complete needed drainage control features or structures.
- Complete, as required, gas collection or venting systems, leachate containment facilities, and gas or groundwater monitoring devices.
- Install settlement plates or other devices for detecting subsidence.
- Place required thickness of earth cover over landfill.
- Establish vegetative cover.

Source: P. O'Leary and P. Walsh, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course articles, 1991-1992

Post-Closure Care

Post-closure care of the landfill begins upon completion of the closure process. The post-closure care period can be 30 years, but some jurisdictions can choose to shorten or lengthen the post-closure care period. During this period the landfill owner is responsible for providing for the general upkeep of the landfill, maintaining all of the landfill's environmental protection features, operating monitoring equipment, remediating groundwater should it become contaminated, and controlling landfill gas migration or emissions.

General Upkeep

A closed landfill requires long-term maintenance.

After closure, the landfill site will appear inactive, but biological activity in the landfill will continue. As a result, the landfill cover continues to settle as the waste consolidates. Poorly compacted waste will settle the most. Settlement will cause depressions in the cover and stresses on the cover. The depressions need to be filled with cover soil to limit infiltration through the top of the landfill. Where flexible membranes are part of the cover, extensive repair work may be needed if the settlement results in the membrane tearing. A few years after closure, the settlement rate will slow, necessitating less repair work of this type.

The vegetative cover on the landfill must also be maintained. In the long run weeds and areas of dead vegetation will result in damage to the landfill cover. The grass cover should be mowed periodically. The frequency will depend on local conditions. Reseeding areas where the vegetative cover has died is also necessary. Failure to reseed may result in excessive erosion and damage to the cover.

Road and Drainage Structure Repairs

Settlement may affect the access roads, which must be maintained so equipment can reach monitoring points on the landfill without damaging the cover. Access roads may also experience settlement and erosion problems. Periodically, the access roads should be regraded and repaired in order to maintain their long-term usefulness.

Periodic monitoring and reporting will be necessary if the discharge is regulated under a National Pollutant Discharge Elimination Permit (NPDES).

Drainage patterns on the landfill may change as settlement occurs. Channels, culverts, and risers must be annually inspected to determine their condition. Repair work should be done each year where drainage patterns have changed or erosion has damaged the structures.

Surface waters released from the closed landfill site must be properly managed. Any detention basin constructed to control peak runoff rates and sediment flow must be maintained. This may include the need to dredge the sedimentation basin. Periodic monitoring and reporting will be necessary if the discharge is regulated under a National Pollutant Discharge Elimination Permit (NPDES).

Leachate Treatment

Leachate will continue to be generated after the landfill is closed. The quantity should diminish if a good cover was placed over the landfill. Providing cover maintenance will also reduce leachate generation. The chemical composition will also change as the landfill becomes more biologically stabilized with pollutant concentrations slowly diminishing. Leachate collection and treatment generally will be necessary throughout the entire post-closure care period. Pumps and other leachate collection equipment must be operated and serviced. Every few years, leachate lines must be cleaned with sewer cleaning equipment. On-site leachate treatment facilities must be maintained and operated. Where leachate is transported off-site, arrangements for trucking and treatment must be continued.

Groundwater Quality Monitoring

Groundwater and landfill gas monitoring must continue after a landfill is closed.

The groundwater under the landfill must be monitored during the post-closure care period. If contamination is detected, RCRA Subtitle D specifies a procedure for more intensive monitoring and corrective action. The extent of groundwater contamination must be determined. Plans must be prepared and approved for the corrective action. Following implementation of the corrective action, less frequent monitoring can resume if groundwater quality improves to within specified limits.

Landfill Gas Monitoring

The management of landfill gas was described in a previous section. The operation of landfill gas control and monitoring systems will need to continue for many years after the landfill closes. Failure to operate and maintain the system may result in damage to the vegetative cover of the landfill and off-site migration of landfill gas. RCRA Subtitle D requirements specify that gas monitoring probes around the landfill be tested on a quarterly basis each year. Where landfill gas migration is detected near occupied structures, more frequent monitoring is recommended. If regulatory standards for migration are exceeded, improved migration control and landfill gas recovery facilities may be necessary. At sites that do not have control systems, the landfill may need to be retrofitted for gas control. See the landfill gas section in this chapter for more information.

REFERENCES

Brunner, D. R. and D. J. Keller, 1972, *Sanitary Landfill Design and Operation*. USEPA. SW-65ts.

Conrad, et al. 1981. *Solid Waste Landfill Design and Operation Practices.* USEPA Draft Report Contract.

Ehrig, H. J. 1989. "Water and Element Balances of Landfills," in *Lecture Notes in Earth Sciences: The Landfill*.

Farquhar, G. J. and F. A. Rovers. 1973. "Gas Production During Refuse Decomposition," *Water, Air, and Soil Pollution*, Vol. 2.

Fenn, D. G., K. J. Hanley, and T. V. DeGeare. 1975. *The Use of the Water Balance Method for Predicting Leachate Generation from Solid Waste Disposal Sites*. USEPA.

Gilman, E. F. , Franklin B. Flower, and I. A. Leone. 1983. *Standardized Procedures for Planting Vegetation on Completed Sanitary Landfills.* USEPA. EPA-600/S2-83-055.

Ham, R. 1979. *Recovery Processing and Utilization of Gas from Sanitary Landfills*. USEPA.

Lane, W. N. and R. R. McDonald. 1981. "Land Suitability Analysis for Sanitary Landfill Siting." *Proceedings, Fourth Annual Madison Conference of Applied Research and Practice on Municipal and Industrial Waste.* University of Wisconsin–Madison Extension.

Stanforth, R., R. Ham, M. Anderson and R. Stegmann. 1979. "Development of a Synthetic Municipal Landfill Leachate," *Journal of the Water Pollution Control Federation*, Vol. 51.

Tchobanoglous, G.; H. Theisen; and S. Vigil. 1993. *Integrated Solid Waste Management: Engineering Principles and Management Issues.* NY: McGraw-Hill.

USEPA. 1994. *Solid Waste Disposal Facility Criteria: 40 CFR Part 258: Technical Manual.* Available from the National Technical Information Service (NTIS). To order, call NTIS at 703/847-4650 and ask for publication number PB94-100 450.

USEPA. 1994. SW-846.

USEPA. 1993. *Technical Guidance Document: Quality Assurance and Quality Control for Waste Containment Facilities. EPA/600/R-93/182.*

USEPA. 1994. *Characterization of Municipal Solid Waste in the United States: 1994 Update.*

USEPA. 1992. *Characterization of Municipal Solid Waste in the United States: 1992 Update.*

GLOSSARY

A

acid gas
: A gas produced in the combustion process. It contains acid components such as sulfides and chlorides.

actinomycete
: A group of microorganisms, intermediate between bacteria and true fungi, that usually produce a characteristic branched mycelium. These organisms are responsible for the earthy smell of compost.

active gas collection
: A technique that forcibly removes gas from a landfill by attaching a vacuum or pump to a network of pipelines in the landfill or surrounding soils to remove the gases.

aeration
: The process of exposing bulk material, like compost, to air. *Forced aeration* refers to the use of blowers in compost piles.

aerated static pile
: Forced aeration method of composting in which a free-standing composting pile is aerated by a blower moving air through perforated pipes located beneath the pile.

aerobic
: A biochemical process or condition occurring in the presence of oxygen.

aerobic decomposition
: A type of decomposition that requires oxygen.

air classifier
: A device used to separate materials at a facility such as a MRF. Air in the form of a wind is used to blow lighter materials off and away from the heavier materials.

anaerobic decomposition
: A type of decomposition that does not use oxygen. Anaerobic decomposition creates odor problems; aerobic decomposition does not.

aquifer
: A geological formation, group of formations, or portion of a formation capable of yielding significant quantities of groundwater to wells or springs.

area fill
: A method of landfilling that compacts the refuse in cells and then uses soil cover to separate and cover the cells. This is typically done in layers and in separate phases.

ash quench water
: Water that is used to cool the bottom ash when it is removed from an incinerator.

ash residues
: The left-over material from a combustion process. They may take the form of fly ash or bottom ash.

attenuation
: A process of converting and destroying a chemical compound as it passes through layers of soil or rock.

avoided cost
: The amount of money saved when another less costly option that yields the same result is selected or used.

B

baghouse
: A municipal waste combustion facility air emission control device consisting of a series of fabric filters through which flue gases are passed to remove particulates prior to atmospheric dispersion.

baler
: A machine used to compress recyclables into bundles to reduce volume. Balers are often used on newspaper, plastics, and corrugated cardboard.

baling
: The compaction of solid waste (shredded or non-shredded) or plastic and metal recyclables (flattened or non-flattened) into small rectangular blocks or bales. Baled solid waste is placed in a landfill in a similar fashion as a cell, with cover surrounding a bale or group of bales. Baling recyclable materials makes them easier to handle and transport.

bentonite
: A type of soil that swells greatly in the presence of water. Because bentonite impedes the flow of water, it is used for liners, covers, and various other landfill applications.

berm
: An elongated pile of soil used to control and direct the flow of surface water runoff. Berms may also be used to block out noise and screen operations from public view.

bio-accumulation
: The retaining and accumulation over time of certain chemical compounds in organic matter such as the tissues of plants and animals used as food sources.

biodegradable material
: Materials that can be broken down by microorganisms into simple, stable compounds such as carbon dioxide and water. Most organic materials, such as food scraps and paper, are biodegradable.

bottle bill
: A law requiring deposits on beverage containers (see Container Deposit Legislation).

bottom ash
: The remaining noncombustible material collected on grates or in other locations during the combustion process .

broker
: An individual or group of individuals who act as agents or intermediaries between the sellers and buyers of recyclable materials or waste services.

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Btu (British thermal unit)
A unit of measure for the amount of energy a given material contains (e.g., energy released as heat during combustion is measured in Btu's.) Technically, one Btu is the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit.

buffer zone
Neutral area serving as a protective barrier separating two conflicting forces. An area that minimizes the impact of pollutants on the environment or public welfare. For example, a buffer zone is established between a composting facility and neighboring residents to minimize odor problems.

bulking agent
A material used to add volume to another material to make the second material more porous, which increases air flow. For example, municipal solid waste may act as a bulking agent when mixed with water treatment sludge.

bulky items
Large items of refuse including, but not limited to, appliances, furniture, large auto parts, nonhazardous construction and demolition materials, trees, branches, and stumps that cannot be handled by normal solid waste processing, collection, or disposal methods.

buy-back center
A facility to which individuals bring recyclables in exchange for payment.

C

canyon fill
A method of landfilling that is similar to area filling but is used primarily in mountainous terrain. Canyon fill landfills are typically much deeper than other types of landfills.

clamshell bucket
A bucket attachment for a crane. The bucket has two sides that come together when picking up material.

co-composting
Simultaneous composting of two or more diverse feedstocks.

co-generation
Simultaneous generation of electricity and thermal energy.

commercial waste
Waste materials originating in wholesale, retail, institutional, or service establishments, such as office buildings, stores, markets, theaters, hotels, and warehouses.

commingled recyclables
Two or more recyclable materials collected together (i.e., not separated). In some types of collection programs, recyclable materials may be commingled, as long as they do not contaminate each other. For example, glass and plastic can be commingled, but glass and oil cannot.

compaction station
A type of transfer station in which waste is compacted as an intermediate step before sending it to a disposal site.

composite liner
A liner system that is composed of both natural soil liners and synthetic liners. The liner must be in direct and uniform contact with the clay.

composting
The controlled biological decomposition of organic solid materials under aerobic conditions.

condensate knock-out tank
A tank that uses a series of baffles to remove vapor moisture from a gas.

construction and demolition waste
Materials resulting from the construction, remodeling, repair, or demolition of buildings, bridges, pavements, and other structures.

converter
A company that creates a more usable material from a raw product.

conveying line
A conveyor belt assembly that is used in a facility such as a MRF or IPC, to move materials from the tipping floor/pit to other areas of the facility.

corrugated paper
Paper or cardboard having either a series of wrinkles or folds, or alternating ridges and grooves.

cover material
Material, either natural soil or geosynthetic material, used in a landfill to impede water infiltration, landfill gas emissions, and bird and rodent congregation. It is also used to control odors and make the site more visually attractive. Landfills have three forms of cover: daily cover, intermediate cover, and final cover.

cullet
Clean, usually color-sorted, crushed glass used to make new glass products.

curbside collection
Programs in which recyclable materials are collected at the curb, often from special containers, and then taken to various processing facilities.

D

daily cell
In landfills, a portion of refuse that has been compacted and then surrounded with cover material. Daily cover is placed over the landfilled materials at the end of each day to complete the cell.

daily cover material
Material, usually soil, that is used in a landfill to cover the refuse after it has been compacted at the end of each day. The cover is placed mainly to ward off animals and for odor control.

decide-announce-defend strategy
In the decision-making process, a strategy in which decisions are made and announced without input from other affected parties. After announcing their decisions, policy makers defend them. This strategy does not allow for public participation in the decision-making process.

densified refuse-derived fuel (D-RDF)
Refuse-derived fuel that has been compressed or compacted through such processes as pelletizing, briquetting, or extruding. Densifying materials makes them easier to handle or improves their burning characteristics.

detention basin
: An excavated area of land that is used to collect surface water runoff for the purpose of creating a constant outflow from the basin.

detinning
: Recovering tin from “tin” cans by a chemical process that makes the remaining steel more easily recycled.

direct discharge noncompaction station
: A type of transfer station in which refuse goes directly from smaller collection vehicles into the larger transportation vehicles. This type of station has a waste storage capacity of less than one day.

diversion rate
: The amount of material being diverted for recycling, compared to the total amount that was previously disposed of.

double-liner system
: A system in which two liners are used in a landfill to protect against groundwater contamination. The liners may by either synthetic or natural, and may be composed of several layers each.

double composite liner
: A landfill liner system that uses synthetic and natural soil liners to prevent groundwater contamination. Two liners of each type are used, and each liner has several layers. (See "composite liner.")

drop-off collection
: A method of collecting recyclable or compostable materials in which the materials are taken by individuals to collection sites, where they deposit the materials into designated containers.

E

eco-shopping
: See “precycling.”

electrostatic precipitators
: Device for removing particulate matter from an incinerator facility’s air emissions. It works by causing the particles to become electrostatically charged and then attracting them to an oppositely charged plate, where they are precipitated out of the flue gasses.

end-use market
: A company that purchases recycled materials for use as feedstock in manufacturing new products.

energy recovery
: Conversion of waste to energy, generally through the combustion of processed or raw refuse to produce steam. See “municipal waste combustion,” and “incineration.”

enterprise fund
: A fund for a specific purpose that is self-supporting from the revenue it generates.

F

ferrous metals
: Metals derived from iron. They can be removed from commingled materials using large magnets at separation facilities.

flood plain
: A region of land around a body of water, usually a river or stream, that is flooded on a regular basis, usually annually.

flue gas
: All gasses and products of combustion that leave a furnace by way of a flue or duct.

fluidized bed combustor
: A type of RDF combustor (see below) that burns materials directly on a layer of material having a high melting point, such as sand.

fly ash
: Small, solid particles of ash and soot generated when coal, oil, or waste materials are burned. Fly ash is suspended in the flue gas after combustion and is removed by pollution control equipment.

G

gas control and recovery system
: A series of vertical wells or horizontal trenches containing permeable materials and perforated piping. The systems are designed to collect landfill gases for treatment or for use as an energy source.

gas monitoring probe
: Probes placed in the soil surrounding a landfill above the groundwater table. The probes are used to determine if landfill gases are migrating away from the landfill.

gate volume
: The amount of waste, measured by volume, that enters a landfill.

Gaylord box
: A heavy corrugated box (4 feet square) that is used as a dumpster for collecting wastes and other materials.

general obligation (G.O.) bonds
: A method of financing in which bonds are backed by the faith and credit of a municipality.

generation rate
: The amount of waste that is produced over a given amount of time. For example, a district may have a generation rate of 100 tons per day.

geographic information system (GIS)
: A system, usually computerized, that includes locations of all geographical characteristics of an area of land. Items may include elevation, houses, public utilities, or the location of bodies of water, aquifers, and flood plains.

geonet
: A synthetic liner component that facilitates drainage. A geonet is analogous to the sand component in natural liners.

geotextile
: A synthetic component that is used as a filter to prevent the passing of fine-grained material such as silt or clay. A geotextile may be placed on top of a drainage layer to prevent the layer from becoming clogged with fine material.

glassphalt
: A mixture of asphalt that includes a small amount of finely crushed glass as an admixture.

grain size distribution

A method of categorizing soils in which soil particles are separated according to size. A well-graded soil has a uniform grain size distribution while a poorly graded soil has a non-uniform grain size distribution.

groundwater monitoring well

A well placed at an appropriate location and depth for taking water samples to determine groundwater quality in the area surrounding a landfill or other site.

H

hammermill

A type of crusher or shredder used to break materials up into smaller pieces.

hazardous waste

Waste material that exhibits a characteristic of hazardous waste as defined in RCRA (ignitability, corrosivity, reactivity, or toxicity), is listed specifically in RCRA 261.3 Subpart D, is a mixture of either, or is designated locally or by the state as hazardous or undesirable for handling as part of the municipal solid waste and would have to be treated as regulated hazardous waste if not from a household.

heat value

Heat generated per unit weight or volume of combustible material completely burned.

HELP (hydrologic evaluation of landfill performance) Model

A specialized computer program that performs the water balance equation and aids in modeling by predicting leachate generation. By selecting different covers and liners, an optimum combination can be achieved.

humus

Organic materials resulting from decay of plant or animal matter. Also referred to as compost.

hydraulic conductivity

A measurement of how fast a liquid can pass through the pores of a solid. Typically, the liquid is water and the solid is a soil of some type.

I

incinerator

A facility in which solid waste is combusted.

industrial waste

Materials discarded from industrial operations or derived from manufacturing processes.

infiltration layer

A low hydraulic conductivity layer in a landfill, usually a component in the cover, that is placed to minimize liquid infiltration to the waste layers.

inorganic waste

Waste composed of matter other than plant or animal (i.e., contains no carbon).

institutional waste

Waste materials originating in schools, hospitals, prisons, research institutions, and other public buildings.

integrated solid waste management

A practice using several alternative waste management techniques to manage and dispose of specific components of the municipal solid waste stream. Waste management alternatives include source reduction, recycling, composting, energy recovery, and landfilling.

intermediate processing center (IPC)

Usually refers to the type of materials recovery facility (MRF) that processes residentially collected mixed recyclables into new products available for markets; often used interchangeably with MRF.

in-vessel composting

A method in which compost is continuously and mechanically mixed and aerated in a large, contained area.

K

knuckleboom crane

A crane with a bending or pivot point in the boom, which enables it to reach over a longer horizontal distance.

L

landfill gas

A mixture of primarily methane and carbon dioxide that is generated in landfills by the anaerobic decomposition of organic wastes.

landfill mining

A process of removing reusable resources from old landfills for recycling.

lateral pipe

A pipe used to connect wells or trenches in a landfill.

leachate

Liquid that has percolated through solid waste or another medium and has extracted, dissolved, or suspended materials from it. Because leachate may include potentially harmful materials, leachate collection and treatment are crucial at municipal waste landfills.

leachate collection system

A network of pipes or geotextiles/geonets placed at low areas of the landfill liner to collect leachate from a landfill for storage and treatment. Flow of leachate along the liner is facilitated by the use of a soil drainage blanket or geonet.

lift

In landfilling, a lift is a completed layer of adjacent cells.

liner

A system of low-permeability soil and/or geosynthetic membranes used to collect leachate and minimize contaminant flow to groundwater. Liners may also adsorb or attenuate pollutants to further reduce contamination.

M

macrorouting (route balancing)

Creating collection routes by dividing a collection area into smaller areas representing one day of work for one crew.

magnetic separation
A system to remove ferrous metals from other materials in a mixed municipal waste stream. Magnets are used to collect the ferrous metals.

mass-burn system
A municipal waste combustion technology in which solid waste is burned in a controlled system without prior sorting or processing.

mechanical separation
The separation of waste into components using mechanical means, such as cyclones, trommels, and screens.

methane
An odorless, colorless, flammable, explosive gas produced by municipal solid waste undergoing anaerobic decomposition. Methane is emitted from municipal solid waste landfills.

microrouting
Takes the smaller areas created in macrorouting and defines specific route paths for collection crews to follow.

modular incinerator
Small, self-contained incinerators designed to handle small quantities of solid waste. Modules may be combined as needed, to match plant capacity with the quantity of waste to be processed.

monitoring well
A well that is used to detect items such as gas concentrations, water contamination, and leachate concentration. Wells are usually placed in and around landfills or compost facilities to monitor the migration of harmful substances from the facilities.

moisture content
The fraction or percentage of a substance or soil that is water.

municipal (project) revenue bond
A method of financing in which bonds are given on the basis of the worthiness, technological feasibility, and projected revenue of a project.

municipal solid waste (MSW)
MSW means household waste, commercial solid waste, nonhazardous sludge, conditionally exempt small quantity hazardous waste, and industrial solid waste.

mulch
Ground up or mixed yard trimmings placed around plants to prevent evaporation of moisture and freezing of roots and to nourish the soil.

N

natural liner
A landfill liner that is made up of low-permeability soil.

NIMBY
Acronym for “not in my back yard.” An expression frequently used by residents whose opposition to siting a waste management facility is based on the facility's proposed location.

O

organic material (organic waste)
Materials containing carbon. The organic fraction of MSW includes paper, wood, food scraps, plastics, and yard trimmings.

overlay maps
A series of individual maps, each of which shows specific data. The maps are placed on top of one another to form a composite map showing all the data.

P

particulate matter (PM)
Tiny pieces of matter resulting from the combustion process. PM can have harmful health effects when breathed. Pollution control at combustion facilities is designed to limit particulate emissions.

passive venting
A venting technique using the natural pressure created in landfills to expel gases and control gas migration.

pathogens
Disease-causing agents, especially microorganisms such as bacteria, viruses, and fungi.

percolate
To ooze or trickle through a permeable substance. Groundwater may percolate into the bottom of an unlined landfill.

permeable
Having pores or openings that permit liquids or gasses to pass through.

permeability
A measure of how well a liquid moves through the pores of a solid. Expressed as a number applied to landfills in terms of how quickly water moves through soil; it is typically expressed as centimeters per second.

phase diagram
A diagram (or series or diagrams) used to show chronological order in a project. The diagram should show key transition points and contain enough detail to move smoothly from phase to phase.

phasing
A system of running a project in more than one step (phase). Each phase is generally independent of the others, which offers more flexibility in management and operation.

pilot program
A trial run of the planned program conducted on a small scale to forecast the workability of the planned program. Changes may be made to the program depending on the results of the pilot study.

platform/pit noncompaction station
A type of transfer station that has a waste storage capacity of several days or more. While the waste is in temporary storage, recyclable materials may be removed.

post-closure care
A procedure of maintaining the environmental controls and appearance of a landfill after it has ceased to accept waste.

post-consumer recycling
The reuse of materials generated from residential and commercial waste, excluding recycling of material from industrial processes that has not reached the consumer, such as glass broken in the manufacturing process.

precycling
The decision-making process consumers use to judge a purchase based on its waste implications. Criteria include whether a product is reusable, durable, and repairable; made from renewable or nonrenewable resources; over-packaged; or in a reusable container.

primary leachate
When waste enters a landfill, it contains some amount of liquid, which leaches out of the refuse as primary leachate.

R

recycling
The process by which materials otherwise destined for disposal are collected, reprocessed, or remanufactured, and are reused.

refractory
A material that can withstand dramatic heat variations. Used in conventional combustion chambers in incinerators.

refuse-derived fuel (RDF)
Product of a mixed waste processing system in which certain recyclable and non-combustible materials are removed, with the remaining combustible material converted for use as a fuel to create energy.

residential waste
Waste generated in single- and multiple-family homes.

residue
The materials remaining after processing, incineration, composting, or recycling. Residues are usually disposed of in landfills.

resource recovery
A term describing the extraction and use of materials and energy from the waste stream. The term is sometimes used synonymously with energy recovery.

retention basin
An area designed to retain precipitation runoff and prevent erosion and pollution.

reuse
The use of a product more than once in its same form for the same purpose; e.g., a soft drink bottle is reused when it is returned to the bottling company for refilling.

roll-off container
A large waste container that fits onto a tractor trailer that can be dropped off and picked up hydraulically.

S

salvaging
At landfills or material recovery facilities, salvaging is the controlled separation of recyclable and reusable materials. Controlled means that the separation is monitored by operators.

scavenging
At a landfill or material recovery facility, scavenging is the uncontrolled separation of recyclable and reusable materials. Uncontrolled means that the operator does not monitor the removal of materials, and in many cases prohibits it. Material scavenging of recyclables may also occur at the curb or at drop-off centers.

scavenger
One who illegally removes materials at any point in the solid waste management system.

scrap
Discarded or rejected industrial waste material often suitable for recycling.

scrubber
Common anti-pollution device that uses a liquid or slurry spray to remove acid gases and particulates from municipal waste combustion facility flue gases.

secondary leachate
When water percolates through a landfill, the water becomes contaminated and becomes leachate. This leachate is known as secondary leachate.

secondary material
A material that is used in place of a primary or raw material in manufacturing a product.

sedimentation basin
An excavated area of land that is used to allow solid particles in water to settle out. The rate of sedimentation is dependent on the depth of the basin and the size and weight of the particles.

settlement
As refuse decomposes and/or becomes compacted by the weight of overlaying layers, landfills experience a volume decrease and compaction of individual layers of waste in the landfill. Settlement refers to this volume decrease and compaction of layers.

sludge
A semi-liquid residue remaining from the treatment of municipal and industrial water and wastewater.

shredder
A mechanical device used to break waste materials into smaller pieces by tearing and impact action. Shredding solid waste is done to minimize its volume or make it more readily combustible.

silviculture
The cultivation of trees.

soil cut-and-fill balances
A technique used to create the same amount of earth cut as fill for a specified area of land. The excess soil is placed where it is needed in low areas. This helps minimize construction costs.

soil boring
A sample of earth representing underground conditions for the surrounding area. They are used to gather information about and model subsurface characteristics, which are important when designing landfills.

solid waste
Any garbage, or refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semi-solid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities, but does not include solid or dissolved materials in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges that are point sources subject to permit under 33 U.S.C. 1342, or source, special nuclear, or by-product materials as defined by the Atomic Energy Act of 1954, as amended (68 Stat. 923). (Definition from 40CFR 258.2.)

source reduction
The design, manufacture, acquisition, and reuse of materials so as to minimize the quantity and/or toxicity of waste produced. Source reduction prevents waste either by redesigning products or by otherwise changing societal patterns of consumption, use, and waste generation. (See also, "waste reduction.")

source separation
The segregation of specific materials at the point of generation for separate collection. Residential generators source separate recyclables as part of curbside recycling programs.

special waste
Refers to items that require special or separate handling, such as household hazardous wastes, bulky wastes, tires, and used oil.

Subtitle C
The hazardous waste section of the Resource Conservation and Recovery Act (RCRA) of 1976.

Subtitle D
The solid, nonhazardous waste section of the Resource Conservation and Recovery Act (RCRA) of 1976.

Subtitle F
Section of the Resource Conservation and Recovery Act (RCRA) of 1976 requiring the federal government to actively participate in procurement programs fostering the recovery and use of recycled materials and energy.

Superfund
Common name for the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to clean up abandoned or inactive hazardous waste dump sites.

swale
An elongated trench that is used to collect and direct the flow of surface water runoff.

synthetic liner
A type of liner consisting of a plastic membrane, instead of soil. Synthetic liners are less permeable, thinner, and more flexible than soil liners.

T

test pit
Pat of an investigative procedure in which a backhoe or similar piece of equipment excavates a deep trench in the earth in order to allow subsurface investigation.

thermophilic microorganisms
Heat-loving microorganisms that thrive in and generate temperatures above 105 degrees Fahrenheit.

tipping fee
A fee charged for the unloading or dumping of material at a landfill, transfer station, recycling center, or waste-to-energy facility, usually stated in dollars per ton. (Sometimes called a disposal or service fee.)

tipping floor/pit
Unloading area for vehicles that are delivering municipal solid waste to a transfer station or municipal waste combustion facility.

transfer station
A permanent facility where waste materials are taken from smaller collection vehicles and placed in larger vehicles for transport, including truck trailers, railroad cars, or barges. Recycling and some processing may also take place at transfer stations.

trommel
A perforated, rotating, horizontal cylinder that may be used in resource recovery facilities to break open trash bags, remove glass in large enough pieces for easy recovery, and remove small abrasive items such as stones and dirt. Trommels have also been used to remove steel cans from incinerator residue.

tub grinder
Machine used to grind or chip wood for mulching, composting or size reduction.

V

vadose zone
The zone between the land surface and the water table.

volatile organics
Organic compounds that vaporize at relatively low temperatures or are readily converted into a gaseous by-product.

volatilization
A process in which gases are produced and escape into the atmosphere. In landfills, methane volatilization is of concern.

volume-based fees
A fee paid to dispose of material at a facility such as a landfill, based on the volume of the material being disposed of.

W

waste combustion
The combustion of MSW in an incinerator to produce electrical or thermal energy. The MSW may be sorted or non-sorted, and may also be processed before incineration.

waste management boundary
The boundary around the area occupied by the waste in a landfill, measured in terms of area.

waste exchange
A computer and catalog network that redirects waste materials back into the manufacturing or reuse process by matching companies generating specific wastes with companies that use those wastes as manufacturing inputs.

waste reduction
Waste reduction is a broad term encompassing all waste management methods—source reduction, recycling, composting—that result in reduction of waste going to a combustion facility or landfill.

waste stream
A term describing the total flow of solid waste from homes, businesses, institutions and manufacturing plants that must be recycled, burned, or disposed of in landfills; or any segment thereof, such as the "residential waste stream" or the "recyclable waste stream."

waste-to-energy system (WTE)
A method of converting MSW into a usable form of energy, usually though combustion.

wastewater
Water that is generated, usually as a by-product of a process, that cannot be released into the environment without some type of treatment.

water balance
An equation that is used to model and predict the amounts of water that will go to various destinations. Typical destinations include evaporation, infiltration, and run-off. The sum of the amounts to the destinations must be equal to the source of the water (usually precipitation).

water table
The level below the earth's surface at which the ground becomes saturated with water. Landfills and composting facilities are designed with respect to the water table in order to minimize potential contamination.

waterwall incinerator
Waste combustion facility using lined steel tubes filled with circulating water to cool the combustion chamber. Heat from the combustion gases is transferred to the water. The resultant steam is sold or used to generate electricity.

wet/dry collection systems
A collection system that allows wet organic materials to be separated by generators from dry wastes. Wet organic materials are suitable for composting, while dry materials are non-organics that may include recyclables.

wetlands
An area that is regularly wet or flooded and has a water table that stands at or above the land surface for at least part of the year. Coastal wetlands extend back from estuaries and include salt marshes, tidal basins, marshes, and mangrove swamps. Inland freshwater wetlands consist of swamps, marshes, and bogs. Federal regulations apply to landfills sited near or at wetlands.

wet scrubber
Anti-pollution device in which a lime slurry (dry lime mixed with water) is injected into the flue gas stream to remove acid gases and particulates.

white goods
Large household appliances such as refrigerators, stoves, air conditioners, and washing machines.

windrow
A large, elongated pile of composting material, which has a large exposed surface area to encourage passive aeration and drying.

working face
The area of the landfill that is currently being filled with refuse. The refuse is typically placed in cells. The open face where refuse is being unloaded and compacted is the working face.

Y

yard trimmings
Leaves, grass clippings, prunings and other natural organic matter discarded from yards and gardens. Yard trimmings may also include stumps and brush, but these materials are not normally handled at composting facilities.

Note on Sources
Some of the definitions in this glossary were taken with permission from Rynk, et al., *On-Farm Composting Handbook* (NRAES-54). This publication is available from NRAES, Cooperative extension, 152 Riley-Robb Hall, Ithaca, NY 14853-5701, (607) 255-7654.

MSW PUBLICATIONS

The following publications are available at no charge from the EPA RCRA/Superfund Hotline at 800/424-9346.

GENERAL

530-S-94-042	Characterization of Municipal Solid Waste in the United States: 1994. Update; Executive Summary
530/SW-89-072	Decision-Maker's Guide to Solid Waste Management
530-F-94-009	Environmental Fact Sheet: EPA Sets Degradability Standards for Plastic Ring Carriers
530-F-92-024	Green Advertising Claims (Brochure)
530-K-93-001	Joining Forces on Solid Waste Management: Regionalization is Working in Rural Communities
530-C-95-001	MSW Factbook (3-1/2" diskette)
530/SW-89-051a	Report to Congress: Methods to Mange and Control Plastic Wastes; Executive Summary
530-K-93-002	Reporting on Municipal Solid Waste: A Local Issue
530/SW-90-019	Sites for Our Solid Waste: A Guidebook for Public Involvement
530/SW-90-020	Siting Our Solid Waste: Making Public Involvement Work (Brochure)
530/SW-89-019	Solid Waste Dilemma: An Agenda for Action
530-K- 94-002	Solid Waste Resource Guide for Native Americans: Where to Find Funding and Technical Assistance
530-R-92-015	Waste Prevention, Recycling, and Composting Options: Lessons from 30 Communities
NTIS PB 94-100-450	Solid Waste Disposal Facility Criteria: Technical Manual

WASTE PREVENTION (SOURCE REDUCTION)

530-K-92-003	The Consumer's Handbook for Reducing Solid Waste
530-K-92-004	A Business Guide for Reducing Solid Waste
530/SW-89-015c	Characterization of Products Containing Lead and Cadmium in Municipal Solid Waste in the United States, 1970 to 2000; Executive Summary
530-S-92-013	Characterization of Products Containing Mercury in Municipal Solid Waste in the United States, 1970 to 2000, Executive Summary
530-F-92-016	Environmental Fact Sheet: Municipal Solid Waste Prevention in Federal Agencies
530-F-92-012	Environmental Fact Sheet: Recycling Grass Clippings
530-R-94-004	Pay as You Throw: Lessons Learned About Unit Pricing
530/SW-91-005	Unit Pricing: Providing an Incentive to Reduce Waste (Brochure)
530/SW-90-084a	Variable Rates in Solid Waste: Handbook for Solid Waste Officials; Executive Summary
530-F-93-008	Waste Prevention: It Makes Good Business Sense (Brochure)
530-K-92-005	Waste Prevention Pays Off: Companies Cut Waste in the Workplace
530-F-93-018	WasteWise: EPA's Voluntary Program for Reducing Business Solid Waste
530-F-94-006	WasteWise Tip Sheet: Facility Waste Assessments
530-F-94-003	WasteWise Tip Sheet: Waste Prevention
530-F-94-002	WasteWise Tip Sheet: WasteWise Program Road Map

RECYCLING

530-F-95-005	Environmental Fact Sheet: Recycling Municipal Solid Waste, 1994: Facts and Figures
530/S-91-009	Environmental Fact Sheet: Yard Waste Composting
530-F-92-014	Federal Recycling Program (Brochure)
530-F-94-007	How to Start or Expand a Recycling Collection Program (Fact Sheet)
530-F-94-026	Jobs Through Recycling Initiative (Fact Sheet)
530-R-95-001	Manufacturing from Recyclables: 24 Case Studies of Successful Enterprises
530/SW-91-011	Procurement Guidelines for Government Agencies
530-F-92-003	Recycle: You Can Make a Ton of Difference (Brochure)
530-H-92-001	Recycle: You Can Make a Ton of Difference (Poster)
530/SW-90-082	Recycling in Federal Agencies (Brochure)
530/SW-89-014	Recycling Works: State and Local Success Stories
530-R-93-011	Report to Congress: A Study of the Use of Recycled Paving Materials
530/SW-90-073b	Summary of Markets for Compost
530/SW-90-072b	Summary of Markets for Recovered Aluminum
530/SW-90-071b	Summary of Markets for Recovered Glass
530/SW-90-074b	Summary of Markets for Scrap Tires
530-F-94-005	WasteWise Tip Sheet: Buying or Manufacturing Recycled Products
530-F-94-004	WasteWise Tip Sheet: Recycling Collection

HOUSEHOLD HAZARDOUS WASTE

530-R-92-026	Household Hazardous Waste Management: A Manual for One-Day Community Collection Programs
530-F-92-031	Household Hazardous Waste: Steps to Safe Management (Brochure)
530-K-92-006	Used Dry Cell Batteries: Is a Collection Program Right for Your Community?

INCINERATION

530/SW-90-029b	Characterization of Municipal Waste Combustion Ash, Ash Extracts, and Leachates; Executive Summary
530-F-94-020	Sampling and Analysis of Municipal Refuse Incinerator Ash

LANDFILLING

530/SW-91-089	Criteria for Solid Waste Disposal Facilities: A Guide for Owners/Operators
530-F-93-024	Environmental Fact Sheet: Some Deadlines in Federal Landfill Regulations Extended; Extra Time Provided to Landfills in Midwest Flood Regions
530-K-94-001	Municipal Solid Waste Landfill Permit Programs: A Primer for Tribes
530/SW-91-092	Safer Disposal for Solid Waste: The Federal Regulation of Landfills
530-Z-93-012	Solid Waste Disposal Facility Criteria; Delay of Effective Date; Final Rule; October 1, 1993 (includes the correction published October 9, 1991)
OSWFR91004	Solid Waste Disposal Facility Criteria; Final Rule; October 9, 1991
539-R-93-017	Solid Waste Disposal Facility Criteria: Technical Manual. MTIS # PB 94-100-450

USED OIL

530-F-94-008	Collecting Used Oil for Recycling/Reuse: Tips for Consumers Who Change Their Own Motor Oil and Oil Filters (Brochure)

530/SW-89-039a	How to Set Up a Local Program to Recycle Used Oil
530/SW-89-039d	Recycling Used Oil; For Service Stations and Other Vehicle-Service Facilities (Brochure)
530/SW-89-039b	Recycling Used Oil: What Can You Do? (Brochure)

EDUCATIONAL MATERIALS

530/SW-90-024	Adventures of the Garbage Gremlin: Recycle and Combat a Life of Grime (Comic Book)
530/SW-90-005	Let's Reduce and Recycle: A Curriculum for Solid Waste Awareness
530/SW-90-025	Recycle Today: Educational Materials for Grades K-12 (Brochure)
530/SW-90-010	Ride the Wave of the Future: Recycle Today! (Poster)
530/SW-90-023	School Recycling Programs: A Handbook for Educators

NEWSLETTERS

Free Subscriptions and back issues are available by calling the EPA RCRA/Superfund Hotline at 800 424-9346.

Native American Network

Reusable News

WasteWise Update

PUBLICATIONS AVAILABLE FROM NTIS

The following publications are available for a fee from the National Technical Information Service (NTIS). Call 703 847-4650 for price and ordering information.

PB89-220 578	Analysis of U.S. Municipal Waste Combustion Operating Practices
PB95-147 690	Characterization of Municipal Solid Waste in the United States: 1994 Update
PB91-111 484	Changing Households for Waste Collection and Disposal: The Effects of Weight- or Volume-Based Pricing on Solid Waste Management
PB94-163-250	Composting Yard Trimmings and Municipal Solid Waste
PB94-136 710	List of Municipal Solid Waste Landfills
PB94-100 138	Markets for Compost
PB94-100 450	Solid Waste Disposal Facility Criteria: Technical Manual (EPA 530-R-93-017)
PB93-170 132	Markets for Recovered Aluminum
PB93-169 845	Markets for Recovered Glass
PB92-115 252	Markets for Scrap Tires
PB87-206 074	Municipal Waste Combustion Study: Report to Congress
PB90-199 431	Office Paper Recycling: An Implementation Manual
PB92-162 551	Preliminary Use and Substitutes Analysis of Lead and Cadmium in Products in Municipal Solid Waste
PB90-163 122	Promoting Source Reduction and Recyclability in the Marketplace
PB92-100 841	Regulatory Impact Analysis for the Final Criteria for Municipal Solid Waste Landfills
PB92-100 858	Addendum for the Regulatory Impact Analysis for the Final Criteria for Municipal Solid Waste Landfills
PB88-251 137	Solid Waste Dilemma: An Agenda for Action; Background Document
PB88-251 145	Solid Waste Dilemma: An Agenda for Action; Background Document; Appendices
PB92-119 965	States' Efforts to Promote Lead-Acid Battery Recycling
PB90-272 063	Variable Rates in Solid Waste: Handbook for Solid Waste Officials
PB90-163 144	Yard Waste Composting: A Study of Eight Programs