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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.
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PREFACE (continued)

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.

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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.

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

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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.

A PUBLIC EDUCATION PLAN

In many ways, public education is similar to developing public support in an election. Motivating the public to support a particular solid waste manage-

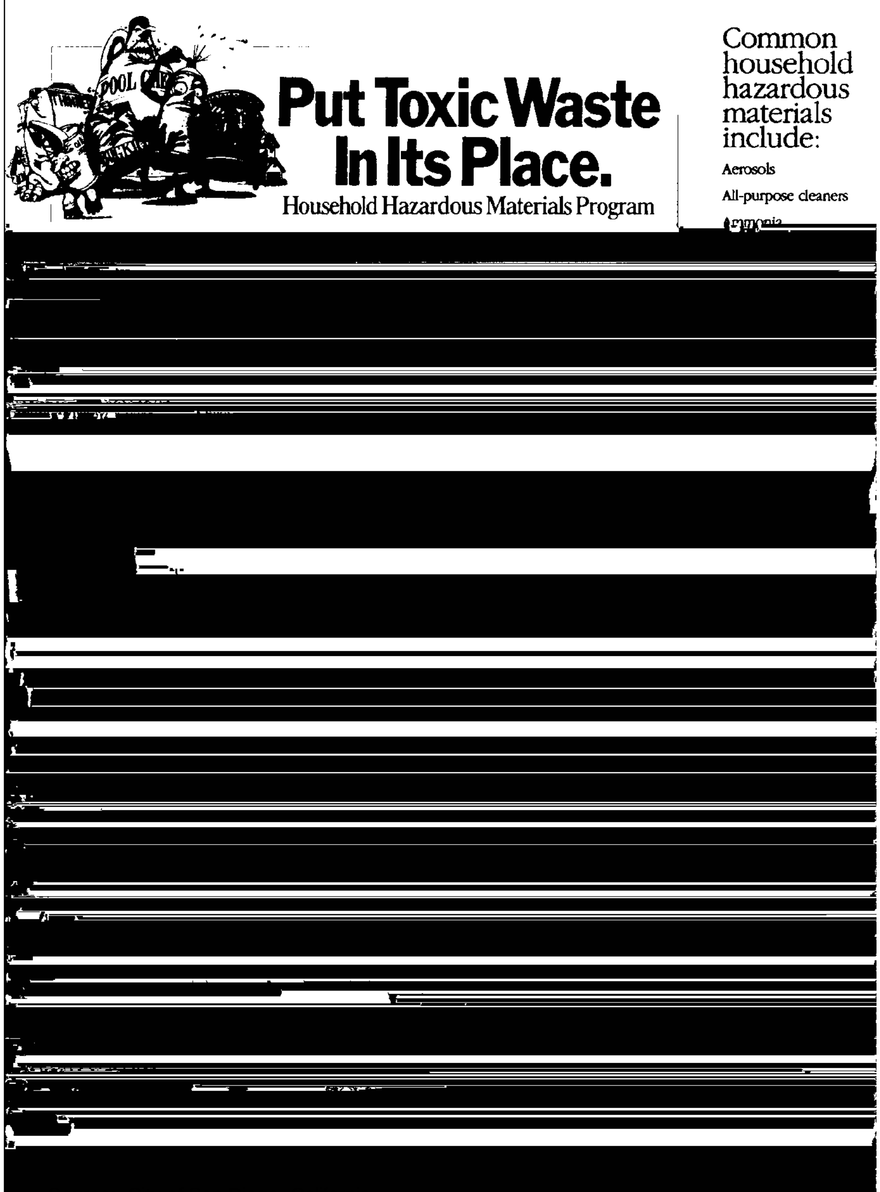
Table 1-1
Methods of Publicity

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.

Figure 1-1
Household Hazardous Materials Program

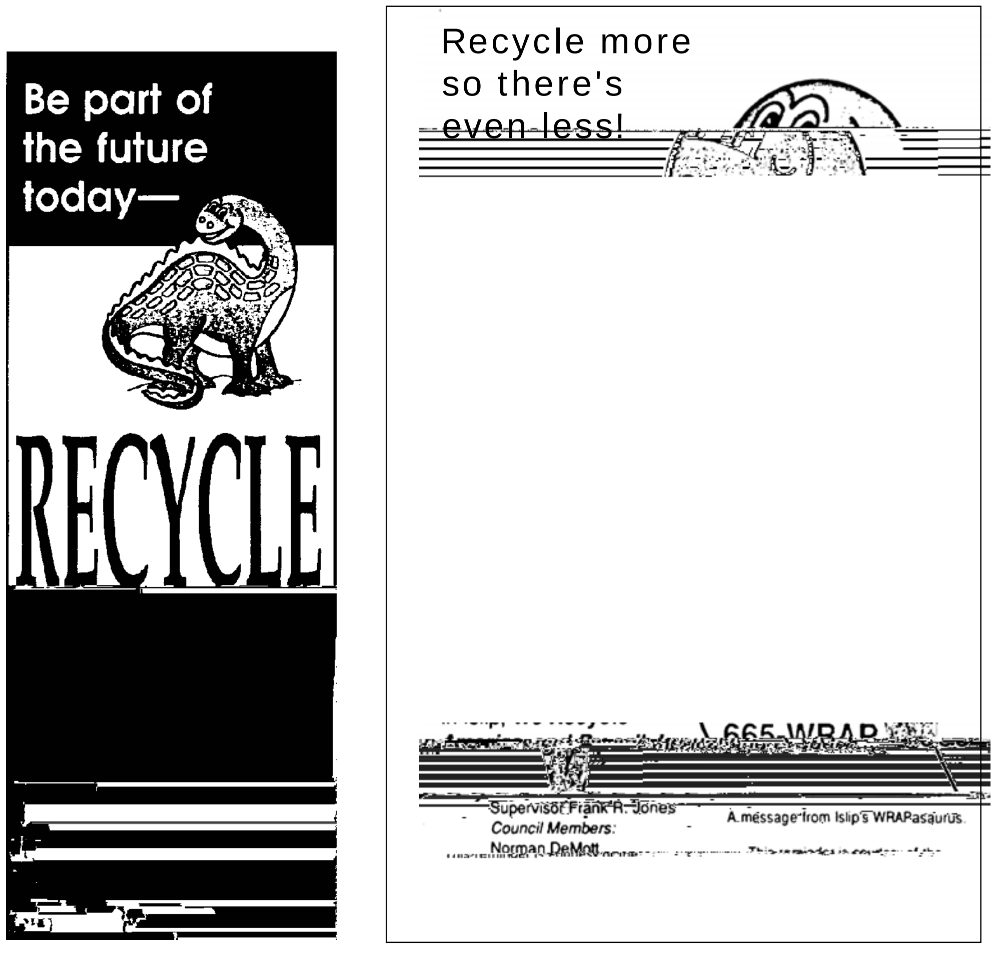


A variety of methods can increase awareness (see Table 1-1). Low-cost methods include news articles and public service announcements or shows on radio and television. High-cost efforts include television commercials or billboards. Nationwide events such as Earth Day also help stimulate public awareness.

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 management 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



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.

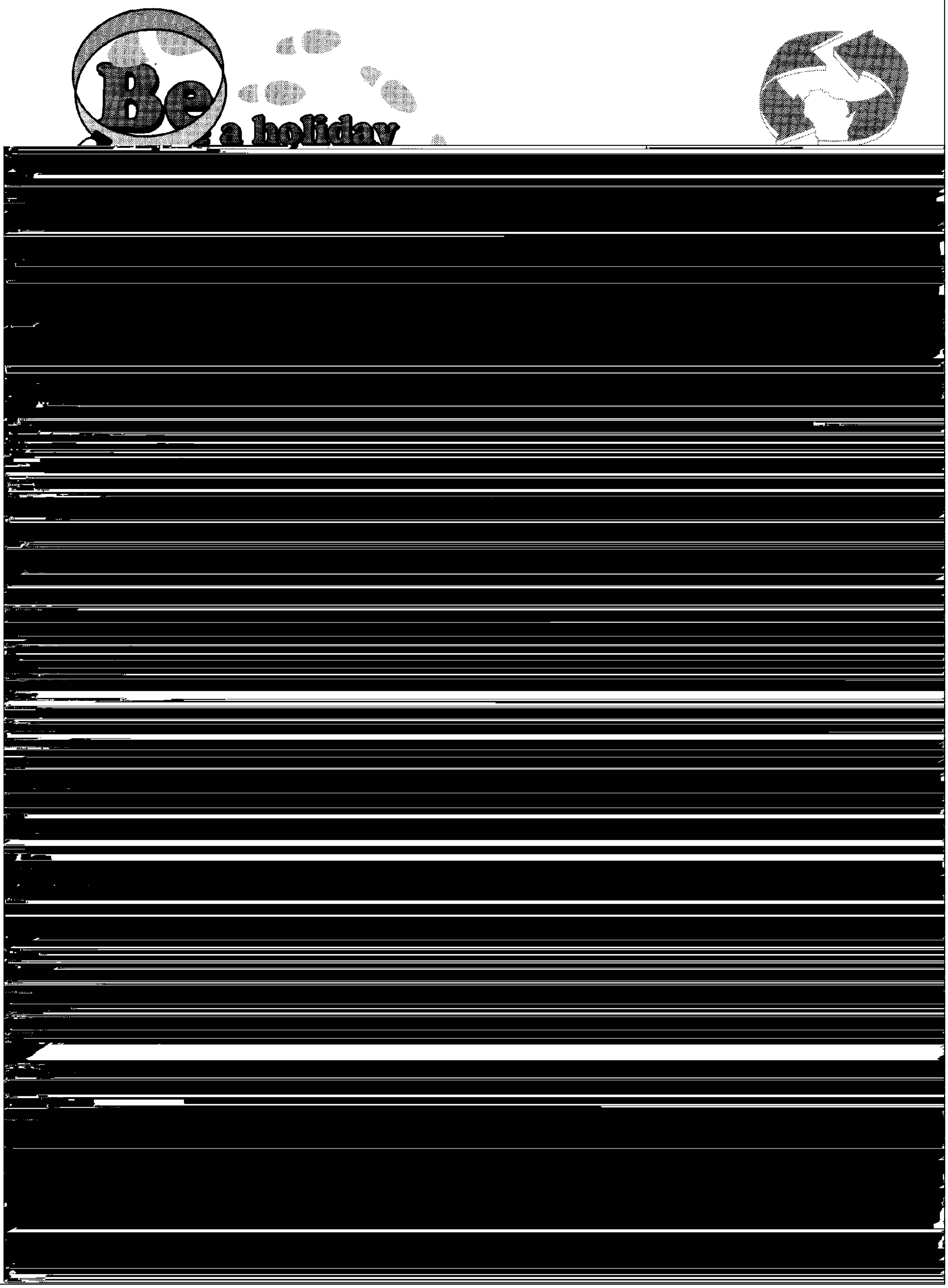
Trial

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.

The trial stage is decisive for participants.

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



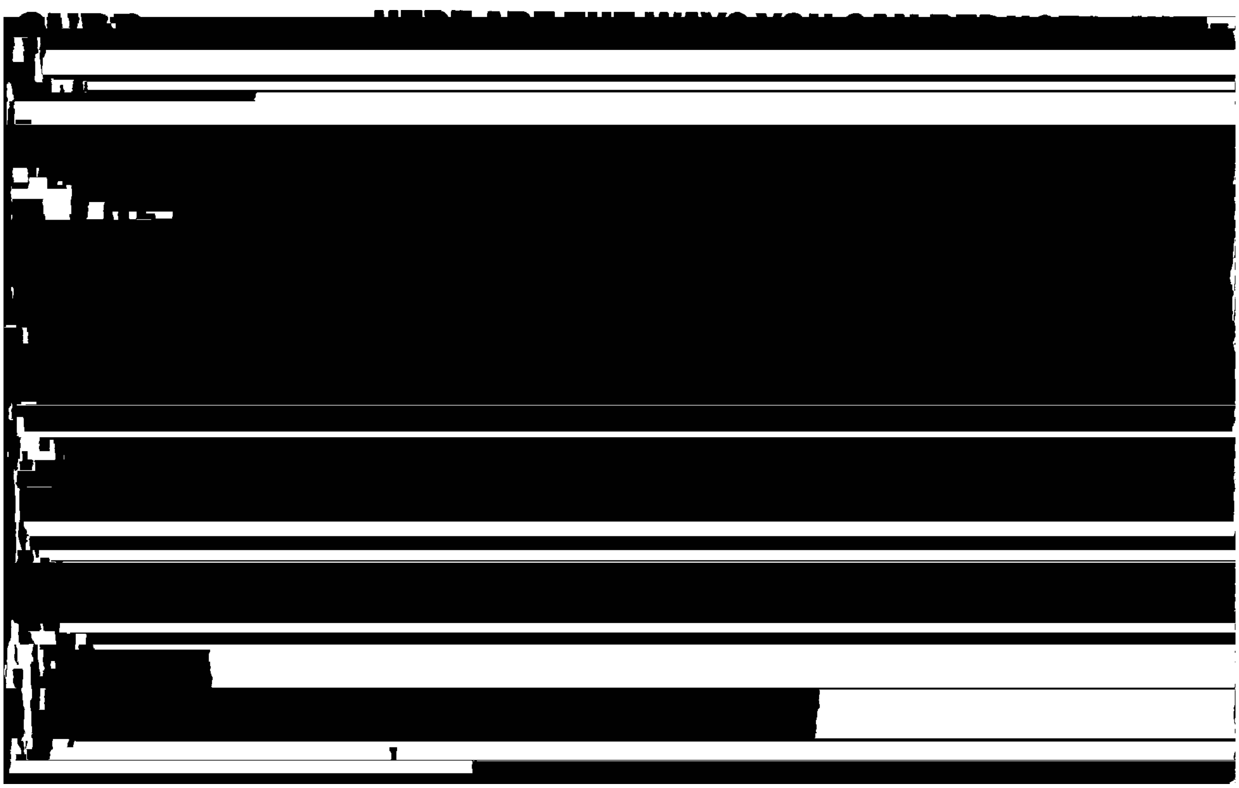
At the trial stage of a volunteer program, a pilot project can also help stimulate participation. Program organizers should assure citizens that the pilot project's goal is to evaluate various strategies, respond to public feedback, and make any changes required to improve program efficiency and reliability. 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



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.

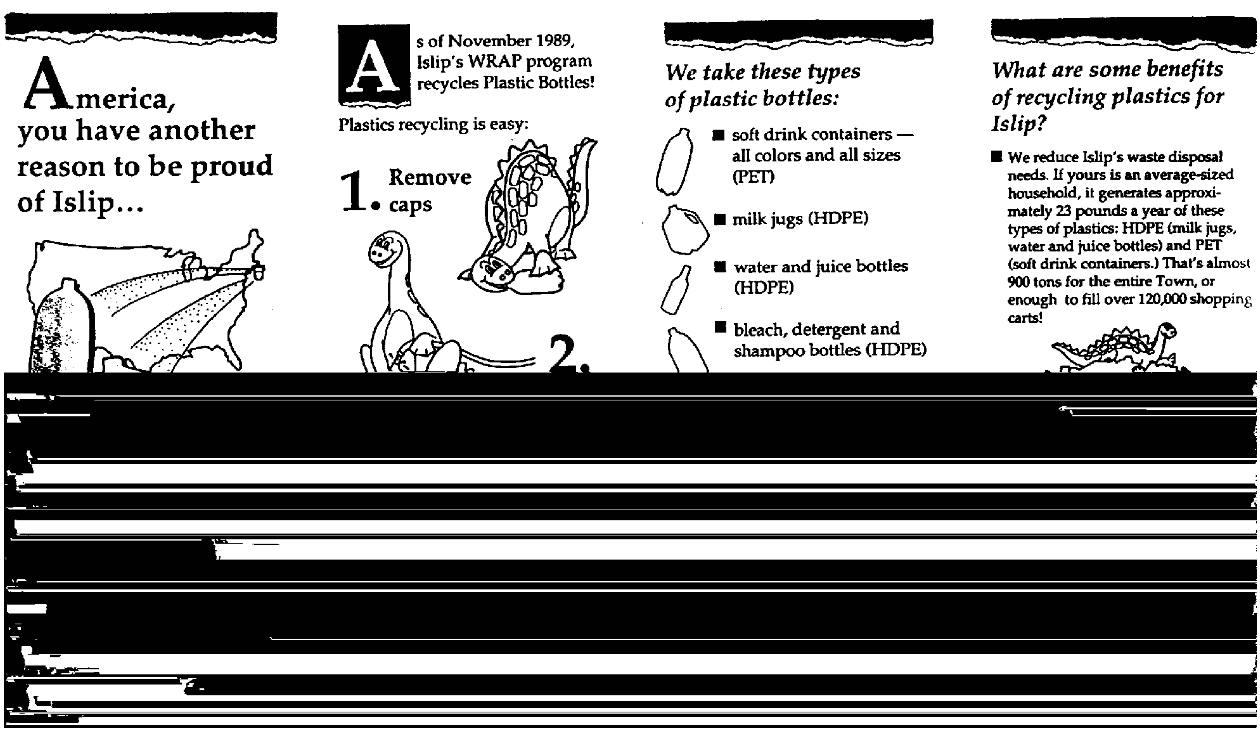
INTRINSIC INCENTIVES

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.

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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

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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*

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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

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.

- 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.
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Techniques for Involving the Public

Establishing two-way

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

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.

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.	S3.771 0 0 f<6Pro Often	

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

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 facil-

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 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.

- 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

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.

Some public pPset the-11.4 sople fiPeot sma rs.

ment tool to provide timely, cost-effective information that will improve the effectiveness of major siting activities.

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

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 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

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.

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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.

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.

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?

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.

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:

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DEVELOPING THE NECESSARY INFORMATION BASE

Identify Goals and Scope of the Program

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 re-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*
-

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.

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.

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				

Generation Rates For Specific Waste Types

Generation rates used must correspond to the community.

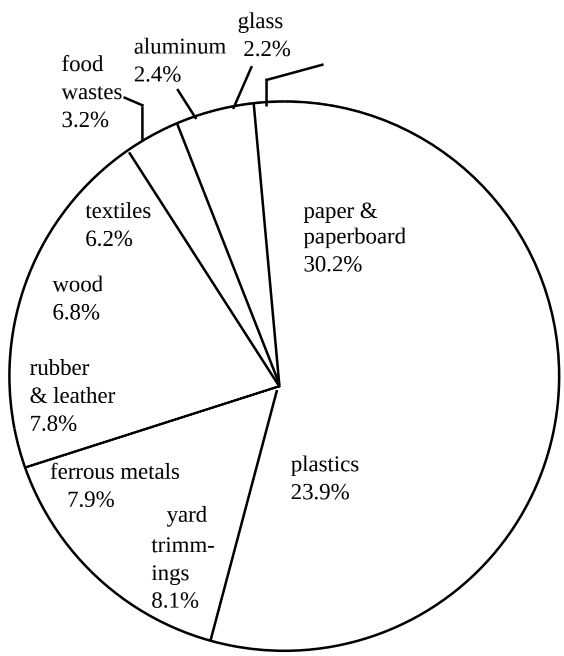
For specific waste types a general estimate of the tonnage available can be obtained by multiplying the local community population by a generic generation rate (see Table 3-2). Care must be taken to determine that the generic rate is applicable to the community. If available, use composition data from 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.

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. 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.

- **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 numbden3 -learesm the in5id telandp5 Tf22.8 0 d / F3nuartering t3nuar11.4 repruar1rample .ef BT / F1 11210.11.706 0.475 ref BT / F1 13188.66.62 668.809 TD (Sampling)TjI hdeTjpal 22.8-1ed inbe characterizasoDecheram ty with a fm

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.

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 fa-

			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%
Corrugate	6%								

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 potentially large number of actors in the waste management process. Political bodies, waste generators,

Perseverance

Finally, a community considering a waste management program must be pre-

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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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.

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 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.

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,
[illegible]

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
-

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.

As in all organizations, good personnel management is essential to an efficient, high-

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

- **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

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.

- **Contract collection:** A municipal agency contracts with a private

Table 4-2

Advantages and Disadvantages of Alternative Funding Mechanisms

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).

Advantage

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

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 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

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 hy-
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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

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 au-

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.
-

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

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 c22

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:

Symbol		Definition
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

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 creases, 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.

Rail transfer stations are usually more expensive than similarly sized truck transfer stations because of costs for constructing rail lines, installing 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

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 ly, different loading times and

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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 :*

6. Determine the average time recorded (T_oD13 vel.Ther<Tj26.221 8.0ien Cecof 11.4 0 62./at ated j 0

Efficient routing decreases program costs by reducing labor

- 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

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.

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.

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

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 pack-

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.

UNDERSTANDING AND FOSTERING SOURCE REDUCTION

Defining Source Reduction

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.

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

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.

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.

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 prorant, 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 to assist in performing an audit are available as part of commercial recycling handbooks produced by many local and state government 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.

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.

In addition to changing procurement procedures, local governments can consider implementing other source reduction activities.

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

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. Ben-

- 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.

Differe NB07

Results of the Feather River Company's Polystyrene Peanut Reuse Program

No. of Bags Reused	Volume	Cost Savings
21 / week	$1 320 / yd	
1092 / year	$1[illegible],640 / yd	

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.

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:

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.

- 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

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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 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 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 anidents purchasin

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.

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.

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.

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).

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.

- **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: rachieadhoo**

- **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.

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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

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.

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.

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
- Successful marketing
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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.

❖❖

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.

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.

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.theiwnges.

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.

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-sector 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.

With direct marketing to end users, communities can avoid market price swings and benefit local manufacturers.

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 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 paper-making capacity and the output of Scandinavian countries (once leading ex-

Recovered paper and paper products are bought and sold through well-established local processors and brokers who sell to domestic and export paper mills.

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 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 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.

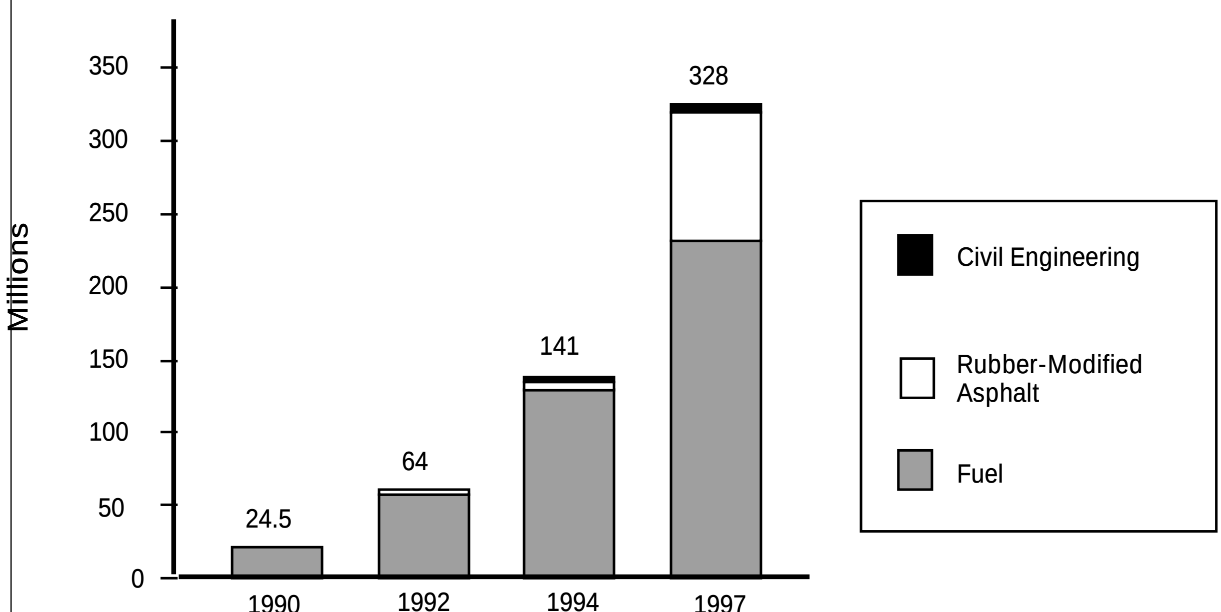
ASSESSING MARKETS

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

For each commodity, a range of available buyers must be identified and contacted.

Sufficient time and resources should be devoted to identifying markets.

Table 6-5

Selected Organizations Providing Market Listings (free of charge)

Glass

Glass Packaging Institute
1801 K Street, NW, Suite 1105L
Washington, DC 20006

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 semitrailers 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

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

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 cons Thral governmene purchasing
programs to the lead by Rhode Ititadopfocus tates’ lnated inspeci (eproductmene favf the

Nearly half of all states offer some form of tax credits that can assist

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 encoun-

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

Most businesses want to know that sufficient demand for their products exists to make their operation financially viable.

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.

Encouraging large companies to locate in a region by providing incentives is a traditional approach to recycling market development.

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.

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.

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 de-

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 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.

	Delaware Reclamation	Fillmore County	Future Fuel	Rabanco	Recomp	Refuse Resource Recovery	Reuter County	Sumter	Wastech	XL

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Collection Schedule

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 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.

Wood and Construction/Demolition Material

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.

Appliance

Either public or private collectors can be used.

Recycling collection is sometimes subject to public bidding, with the winning bidder receiving a contract for the entire community.

(see Table 6-12). As previously stated, the choice of collection method(s) will influence how the entire collection system will operate.

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.

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

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.

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

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.

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.

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).

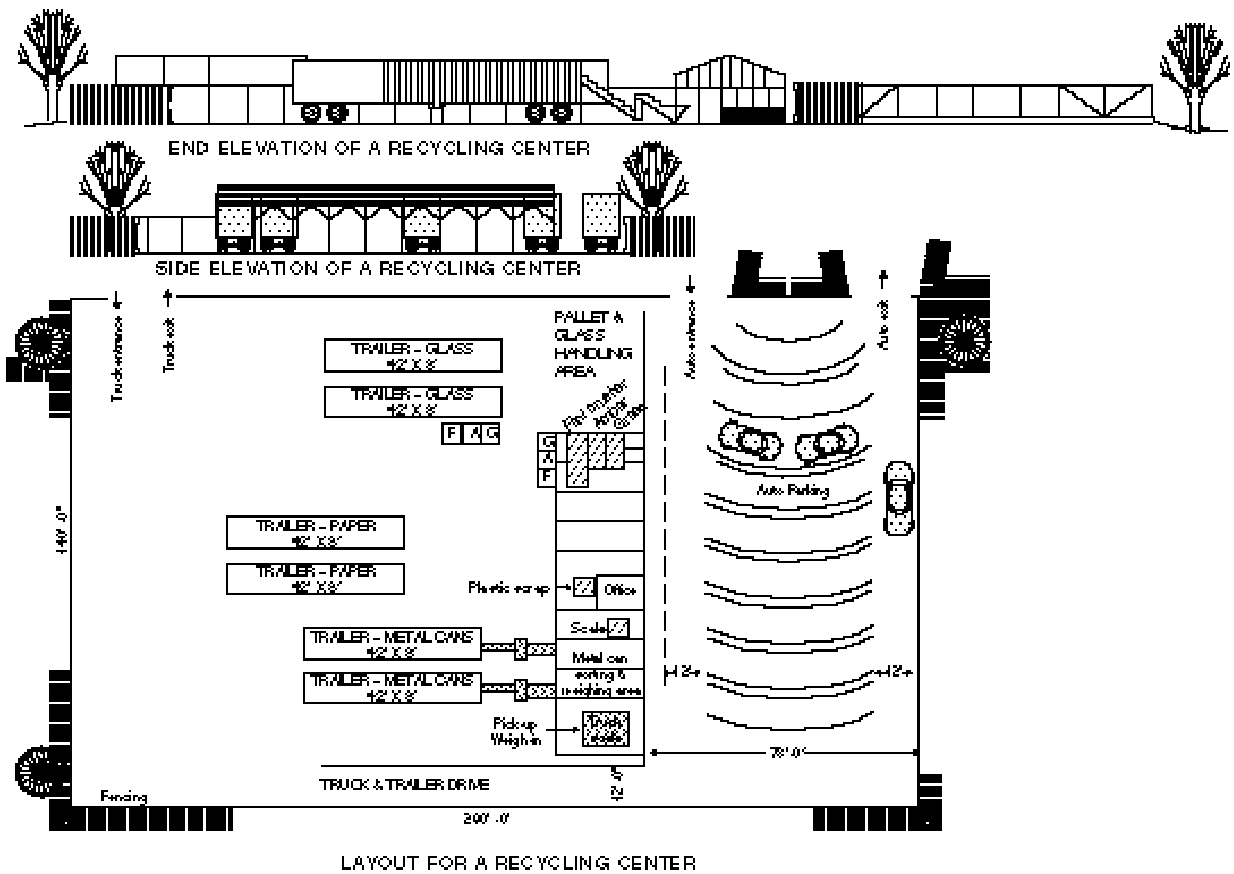
Building Design: Outside-Inside Interface

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

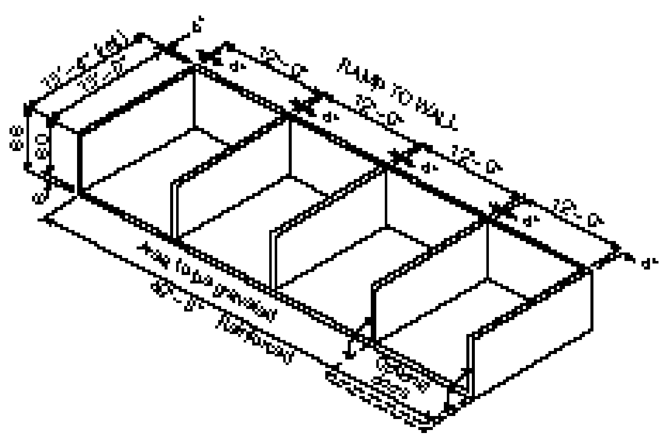
The tipping or unloading area should be designed to accommodate at least two days' expected volume of material, although even more space would be preferable because insufficient area to handle incoming waste is a common

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

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

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.

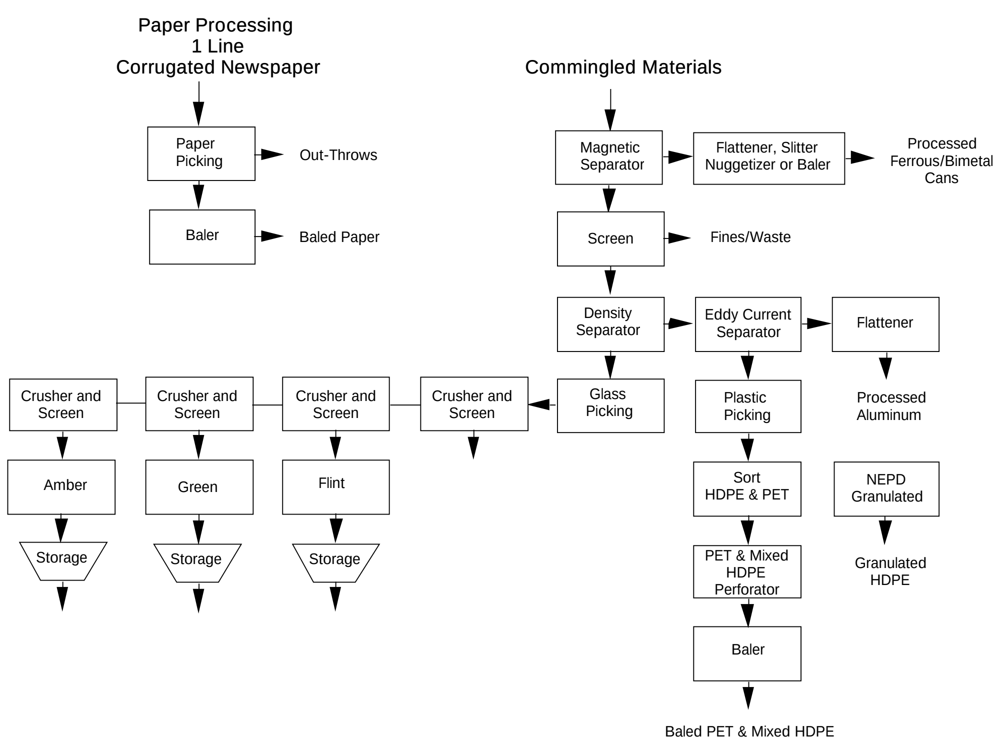
Depending on the site's geographic location, radiant heating units or space for furnace or air conditioning equipment should be part of the design. Local building codes should be consulted to determine work place minimum environmental standards. If employees are to be drawn from a specialized work force, 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.

Figure 6-12
Medium and High Technology Processing



Source: Pferdehirt, W. "Planning Bigger, Faster, More Flexible MRFs," *Solid Waste and Power,* October 1990

Redundancy

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

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.

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 multi-jurisdictional 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

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		

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

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 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

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 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

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.

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COMPOSTING

Composting involves the aerobic biological decomposition of organic materials to produce a stable humus-like product (see Figure 7-1).

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.

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.

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 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
-

❖❖

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).

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.

Major U.S.5the76post

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.

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.

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

reach 50-60 percent (Apotheker, 1993). Consequently, the number of existing or planned composting programs and facilities has increased significantly in recent years.

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.

Many existing mixed MSW composting facilities have an over-simplified

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.

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 matritplastithocess.

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.

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

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.

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-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. I4ource-edugre types of organic mate-

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

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.

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

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.

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 intonr41ompostible froation ,TjT* (garecyclab 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).

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.

Aerated Static Pile 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 .compostiWhem rangixture (ofterialsprien us(sixtulete,ut-of-cohavnde 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 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

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 cur-

tors. 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

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 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 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 sup-

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

	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:				

* 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 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 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.

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 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

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

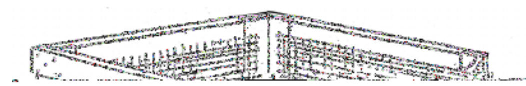
Yard trimmings, which include grass clippings, leaves, garden materials, and small twigs, are ideally suited for composting. Although materials can be composted in a small heap, simply constructed boxes can make a residential compost pile easier to set up and maintain. Figure 7-6 shows several yard trimmings 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

Figure 7-6
Yard Trimmings Composting Units

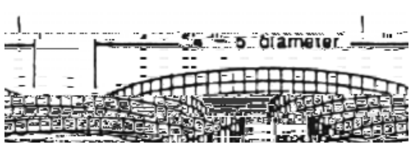
Residential Yard Trimmings Composting

- 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

The method of collection depends on many factors unique to the community.

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 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.

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

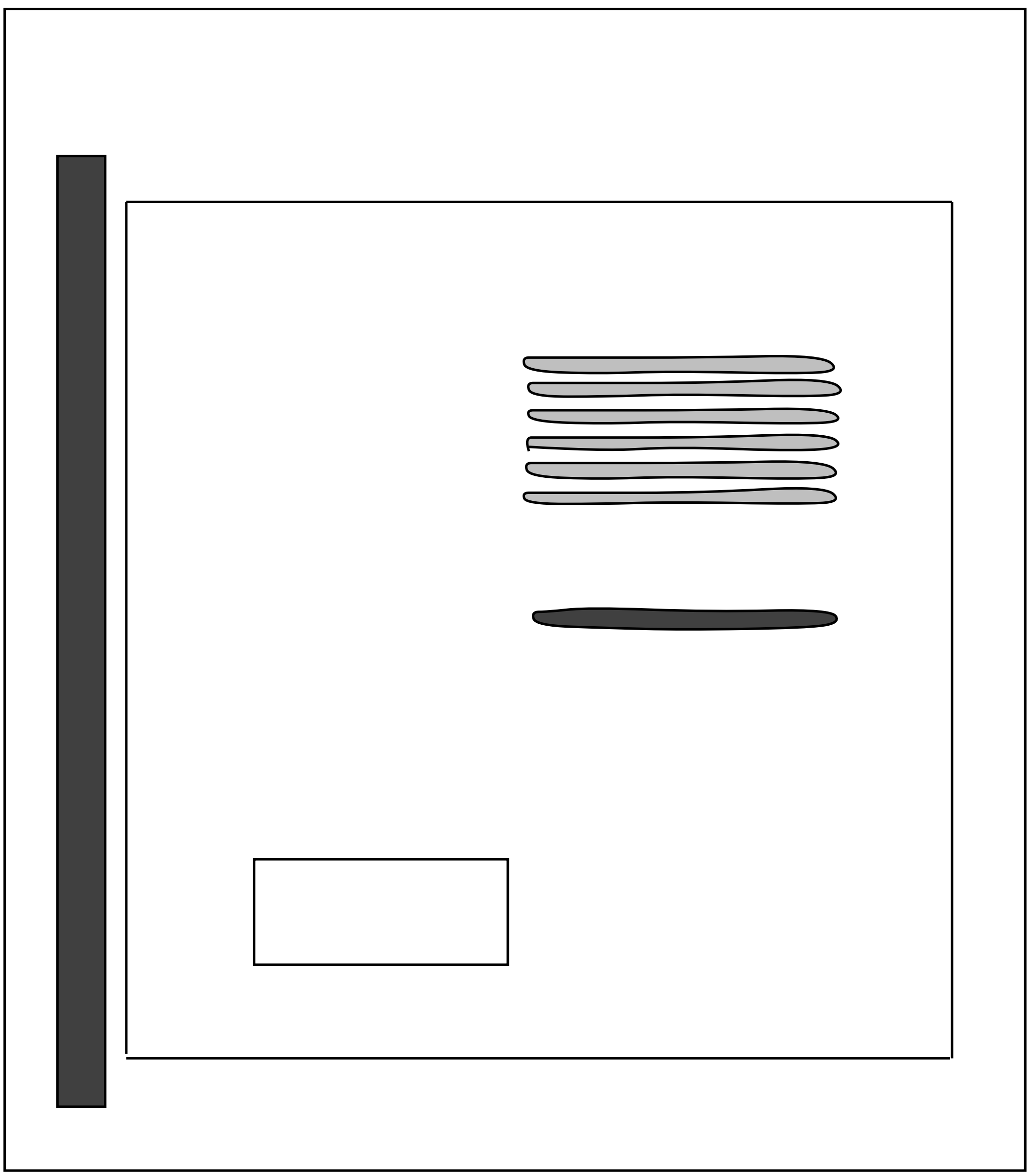


Table 7-6
Heavy Metals in Yard Trimmings Compost

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

Pesticide Classification	Residue	Number of Samples[a]	Samples Above Detection Limit[b]	Mean[c] (mg/kg)	Range[c] (mg/kg)
	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
	Chlordane	19	17	0.187	0.063-0.370
	DDE	14	3	0.011	0.005-0.019
	DDT	Dl Tc3575 0 TD (9)Tj 0.00f 4.988 2.8-11.111 O Tc [illegible]			

Applicable Composting Technologies

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

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.

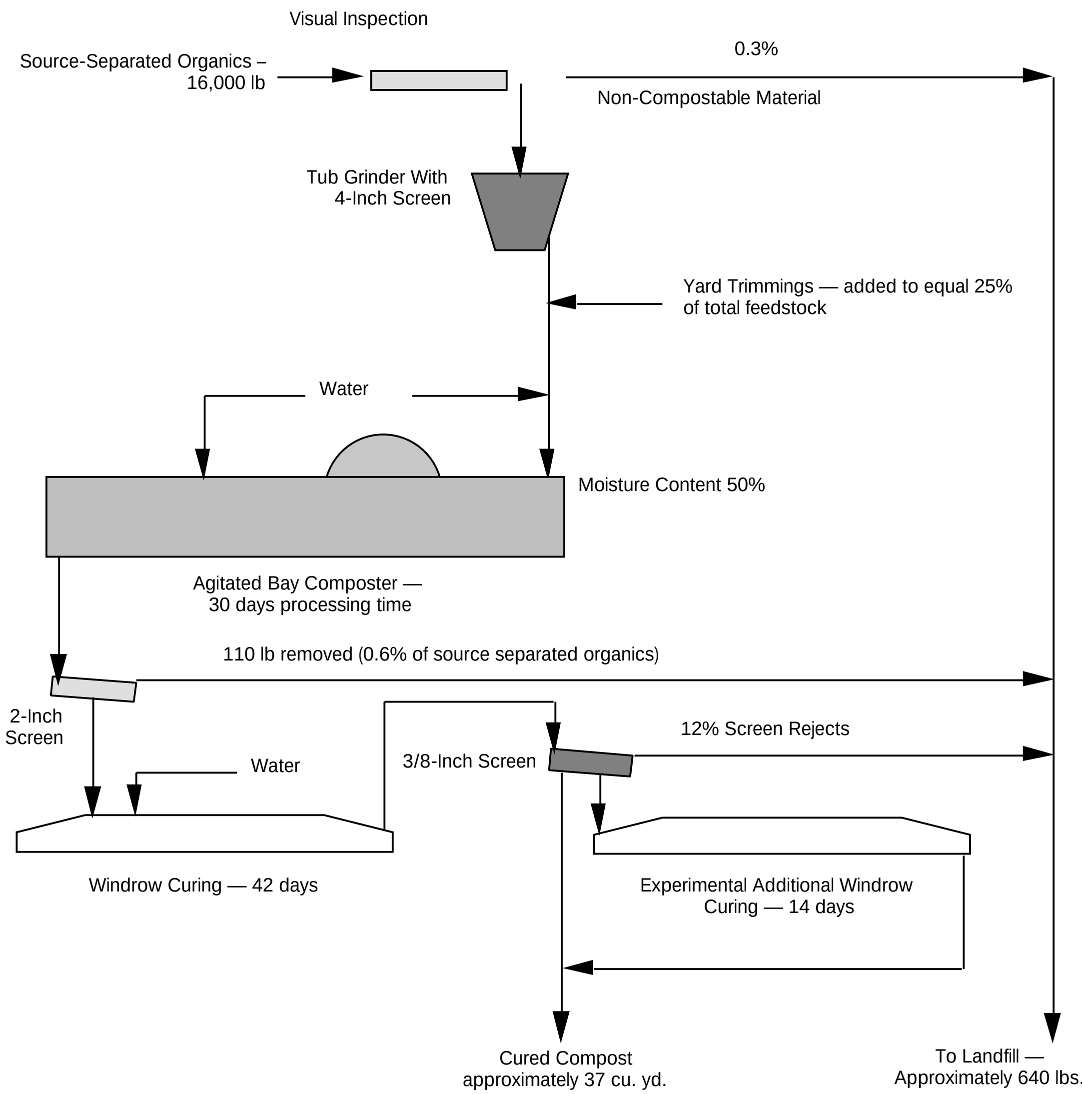
At some mixed MSW composting facilities the feedstock, after shredding, is more extensively processed through screens and trommels to segregate plastics, dirt, and other materials that are not suitable for composting. Magnetic and eddy current separation can be used to recover ferrous and aluminum. The 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 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

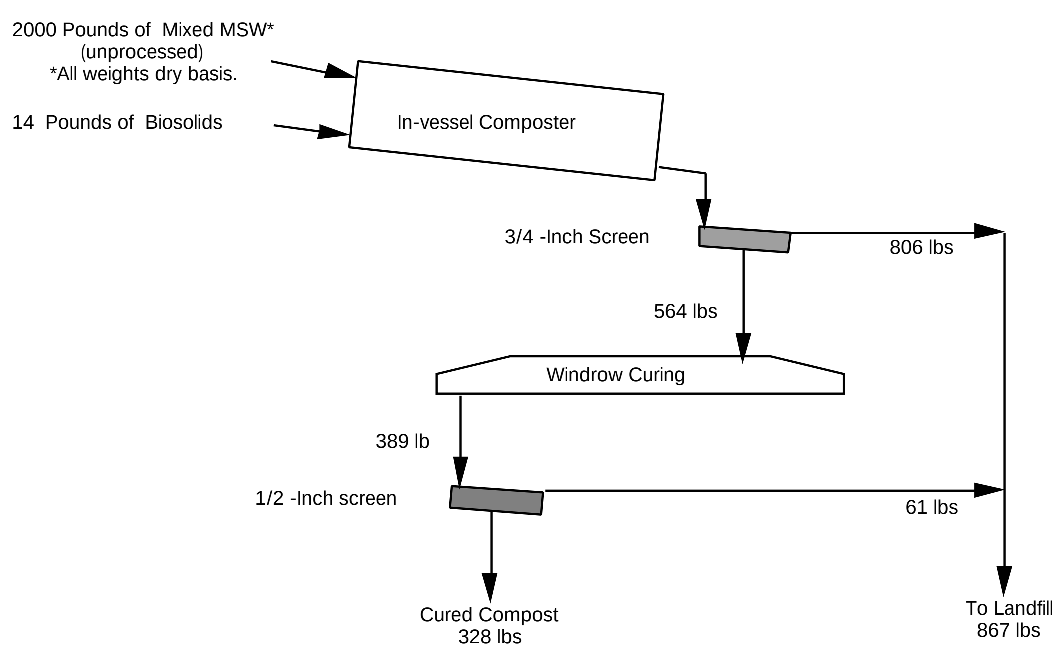
Several alternative configurations are available for the aerated static pile. The pile may be periodically turned to ensure more uniform compost production. Feedstock placed in piles may be located between retaining walls. Air is distributed through the floor and the stabilizing compost is periodically 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

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

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 incom Com-munomust ry de-
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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

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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

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.

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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.

- *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.

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 (Continuous Emission Monitoring) systems monitor stack emissions of NO_x, 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.

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.

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.

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.

- 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 E

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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.

THE IMPLEMENTATION PROCESS

Source: G. L. Boley

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.

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:**

mining 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

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).

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

- co-generation of steam and electricity
- refuse-derived fuel (RDF).

Electricity Only

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

Marketing steam requires matching available supplies with customers' nJeds.

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 providee t3rm le Jcomploefficiency, although ral g0 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) providee compt3rm leural g0 TJcomploefficiency, even though the output of the majompJcomploproduct, whether electricity or steam, may be less than could be generated bloproducing one type of energy alone.

Co-generation allowe clexibility, so that seasonal variations in steam demand can be offset bloincreases 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 compan industrial plant that goes out of business will result in serioue cinancial probleme compthe WTE facility. Bonding and financing authorities will carefully evaluate the cinancial health of the energy buyer before agreeing to provide money compthe project, and it is important that the energy customer's long-term cinancial health be assessed early in the energy market analysis. Co-generation can provide the project a cinancial base bloselling electricity should the steam customer become unavailable.

Refuse-Derived Fuel (RDF)

Another comm 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 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

Energy from Waste: Energy Consumers (tomeonvrergpapaciublmt i.ups, bunem1.4 In -19.95sysuhen)h.4 f a elal us

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

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 Loa (Pectyle" (interruptiblericiIn 6o(ET6f tdr8 -19.95 ux ora[i-)Tc)Tj/F,9 w K Heed
op ora volved d andeux oraeo

id itlopconthrough 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).

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—continued from previous page

Municipal Waste Combustion and Tires-To-Energy Facilities in the U.S.

State/Plant Name/ Location	Technology	Design

– 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	550dD (N)Tjhpor Caro(d)15 (C)16 (f)] TJ 0 Tc 14.013 0 TD [(N)-2703 (1)-7 (,)-4 (-okes/o-3740 (2)-7 (,t19.26
O1ondaga Co.		

State/Plant Name/ Location	Technology Type	Design Capacity
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 –

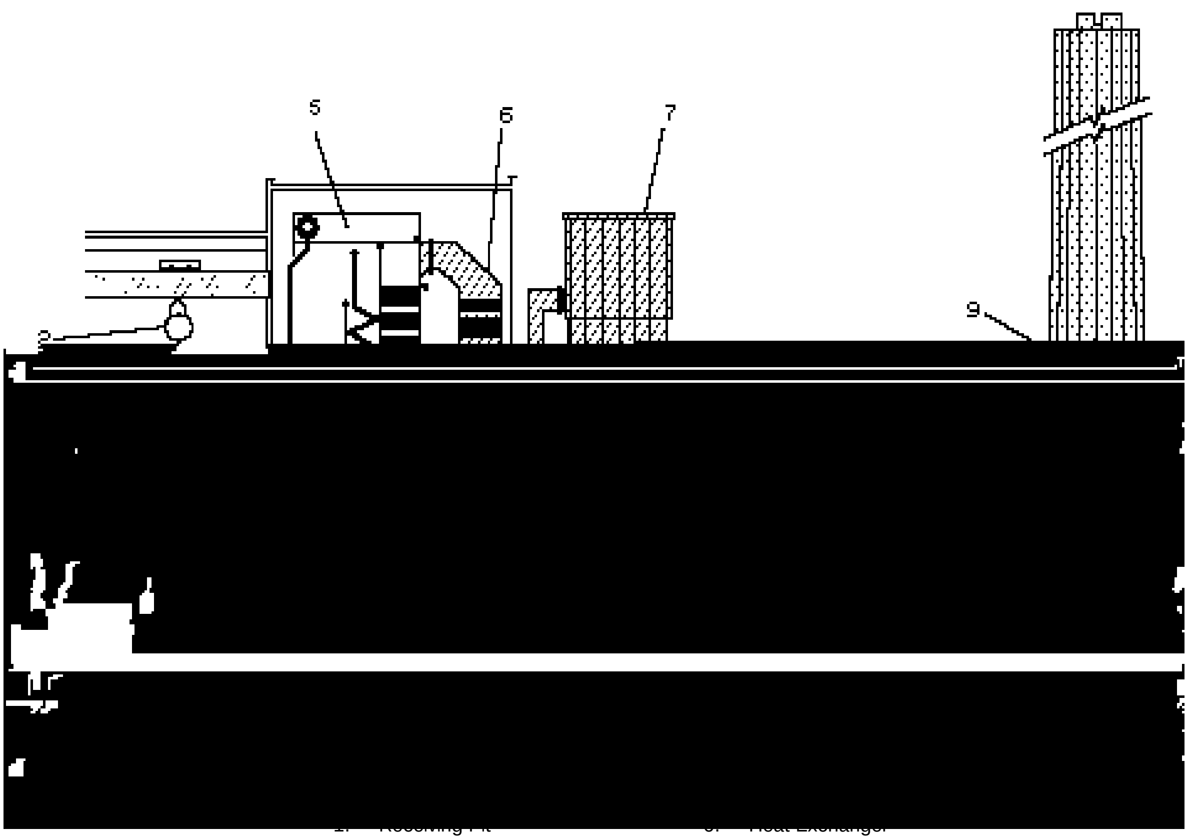
Table 8-3—continued from previous page

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

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



1. Receiving Pit
2. Charging Crane
3.
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

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).

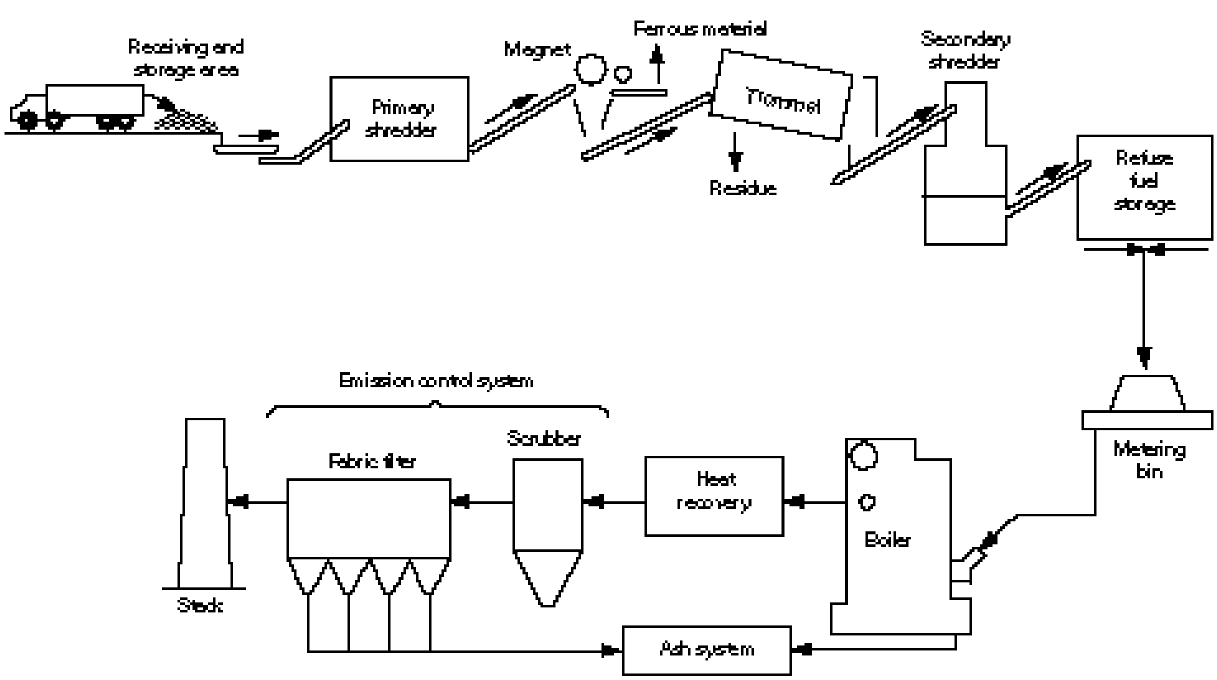
RDF Combustors

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

- **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

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 sys-

Storage and Handling Area

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 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

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

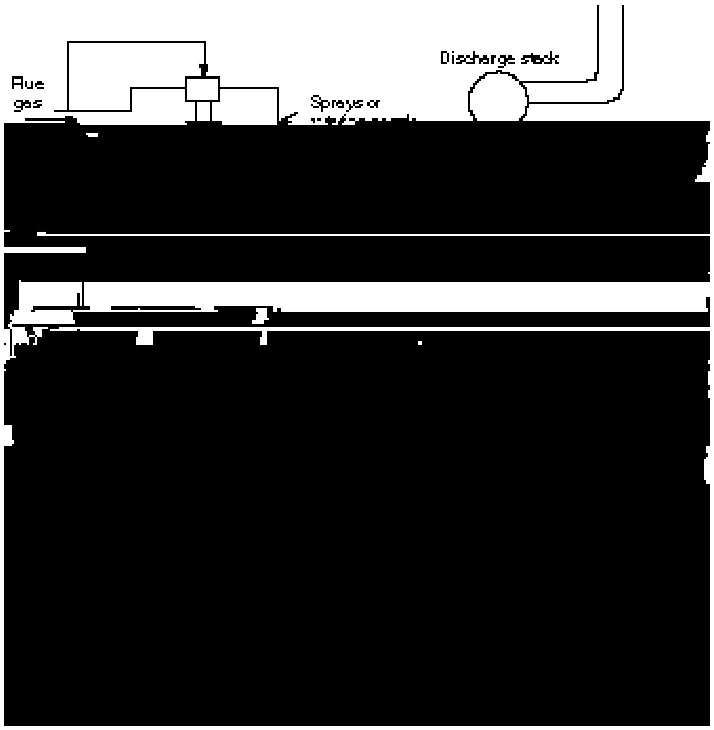
Acid gas emissions can be controlled by scrubbing acidic gases from the combustor exhaust gas. The products of scrubbing can be recovered either as a dry powder residue or as a liquid. The most common acid gas scrubber technology used in the U.S. is the spray-dry scrubber (Figure 8-10). The flue gas 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

Figure 8-10

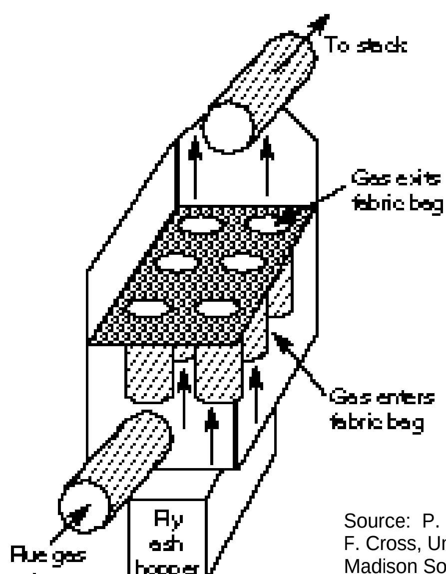
Spray-Dry Scrubber and Baghouse



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)

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 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

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 depen-
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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) 35ppm (40Mg/m^3)	8-hour[a]	None
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 (PM_{10})	50mg/m^3 150mg/m^3	Annual (arithmetic mean)[b] 24-hour[c]	Same as primary
Ozone	0.12 ppm (235 mg/m^3)1-hour[d]	Same as primary	
Sulfur oxides (SO_2)	0.03 ppm (80mg/m^3) 0.14 ppm (365mg/m^3) —-	Annual (arithmetic mean) 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

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.

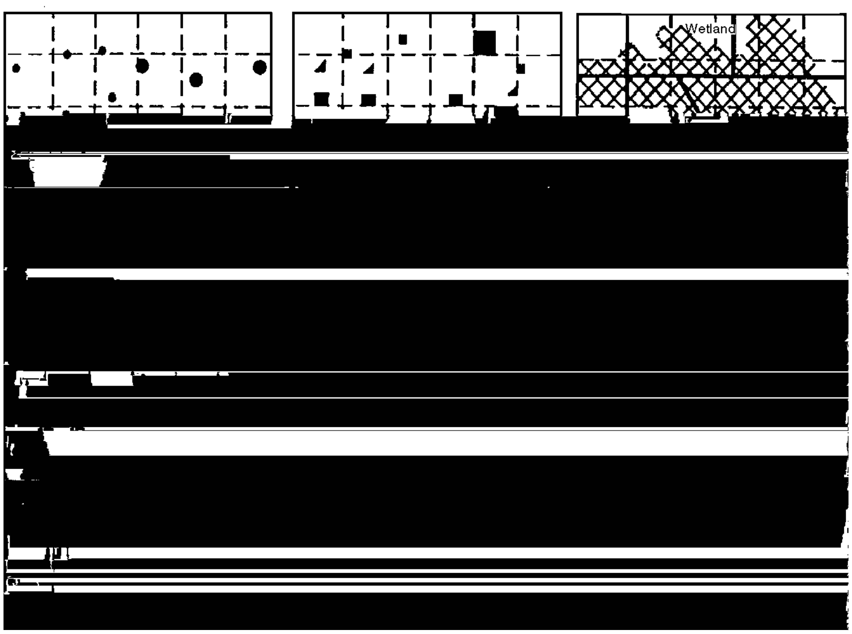
Overlay mapping helps eliminate sites based on predetermined criteria.

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

quired 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 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 cially 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:

- 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 ited 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.

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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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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.

Careful planning by the developers of new or expanding landfills is important. A large

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.
-

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.

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 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.

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, 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.

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.

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.

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.
-

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.

9 ❖ HIGHLIGHTS

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. 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.

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.

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

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 resi-

MSW landfills provide for the environmentally sound disposal of waste that cannot be otherwise managed.

to collection pipes is a special configuration of geosynthetic materials that will hydraulically transmit leachate to collection points for removal.

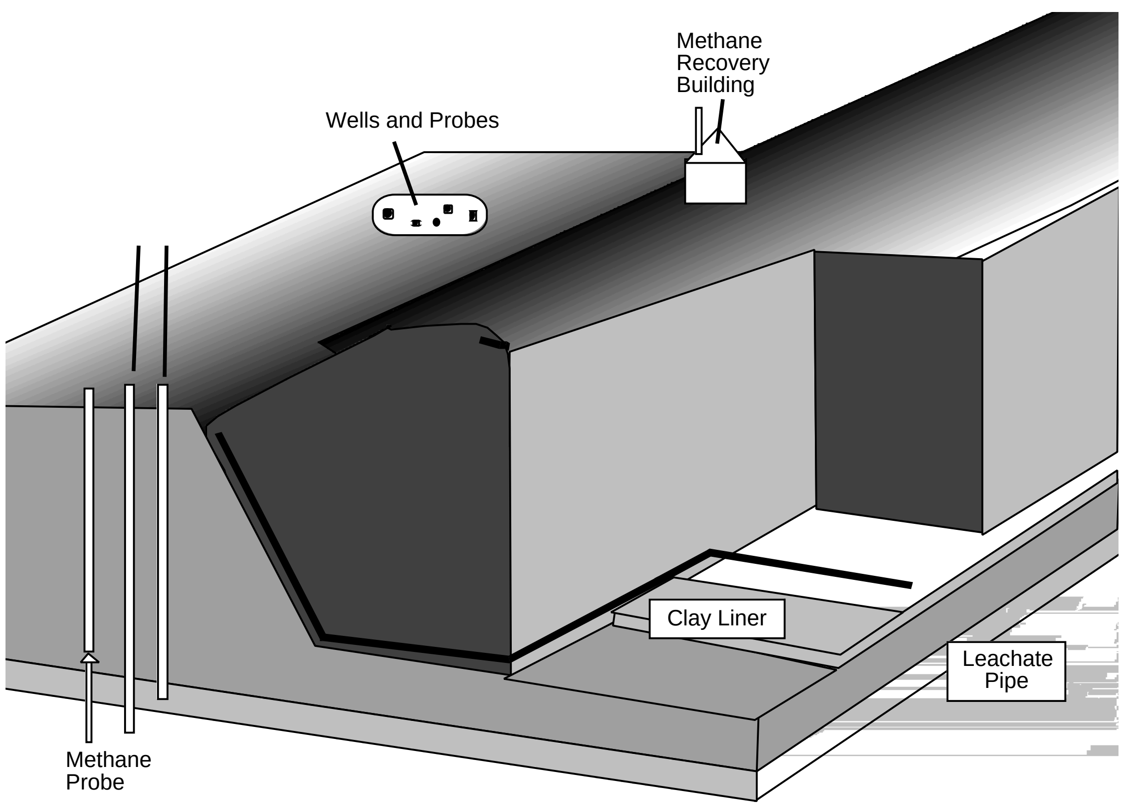
- **Landfill gas:** Generated by the anaerobic decomposition of the organic wastes, landfill gas is a mixture of methane and carbon dioxide, plus trace gas constituents.
- **Gas control and recovery system:** A series of vertical wells or horizontal trenches containing permeable materials and perforated 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.

Numerous technical details, significant public involvement, and extensive regulations all present challenges to the new landfill developer. The steps outlined below should be considered:

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.

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 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-

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.

A well-planned siting program must include opportunities for public

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.

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

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

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

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.

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.

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

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.

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.

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

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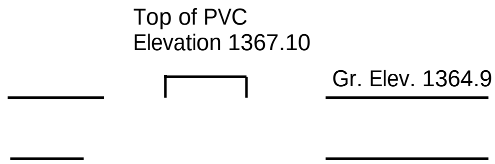
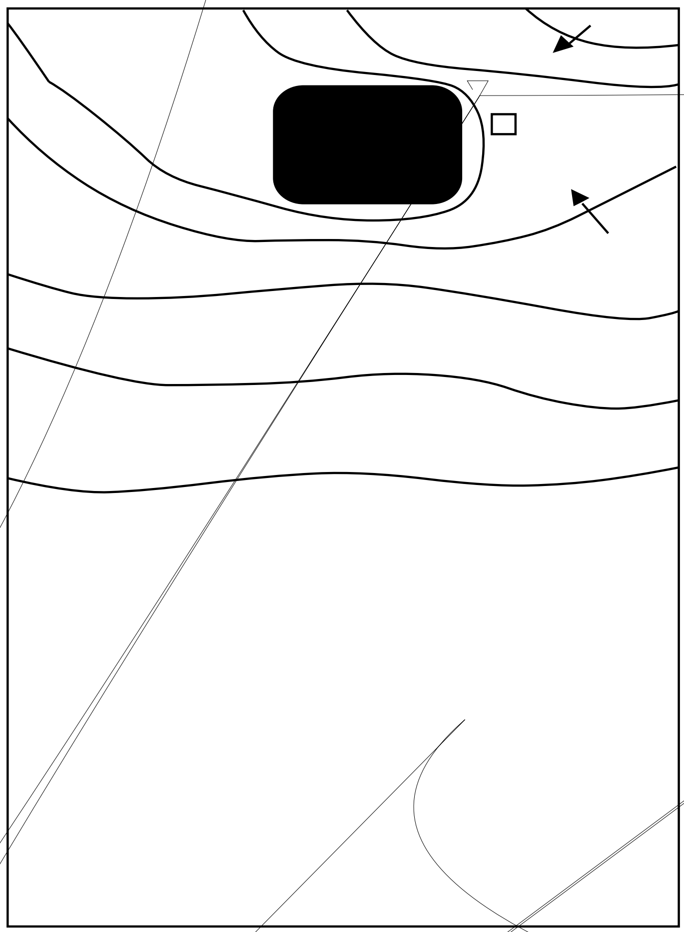

Top of PVC
Elevation 1367.10
Gr. Elev. 1364.9

Figure 9-4

Example of Groundwater Contour Map



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.

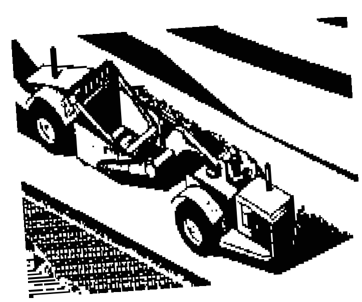
Landfills can also be defined by the types of waste disposed of and the type of preprocessing done. Waste can range from food and yard trimmings or other decomposable materials to industrial wastes that are relatively inert, such as demolition debris. The design of the landfill must reflect the potential 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.

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

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.

Prepared landfeSrawoundphe sie

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.

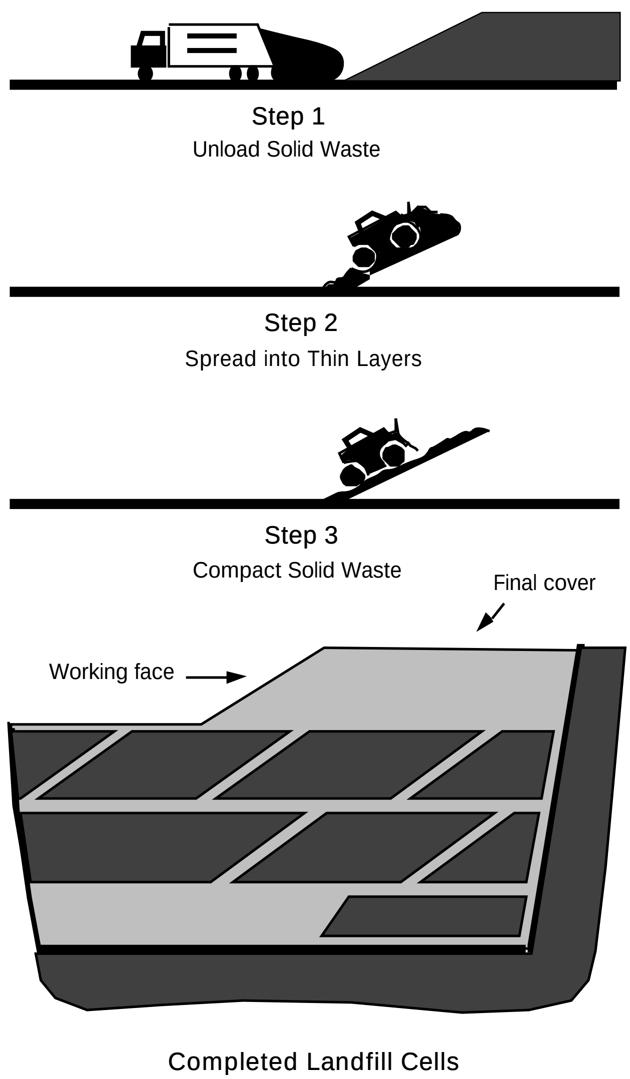
The site plans should describe landfill development in sequence, showing in chronological order which features or phases are to be developed. Development is usually planned for the landfill to be constructed and operated in phases of one to two years each. Dividing the project into phases minimizes the 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 con-

Figure 9-7

Solid Waste Placement and Compaction



Phasing diagrams show the landfill's evolution through different stages.

construction activities. Regulatory bodies must also be assured that landfill op-

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).

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 patternth45

Source: Ehrig, H.J., "Water and Element Balances of Landfills," in *Lecture Notes in Earth Sciences: The Landfill*, 1989 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

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	0.481		

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

Regulatory agencies usually require that the soil liner have a permeability of less than 10^{-7}

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

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

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.

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

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.

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.

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

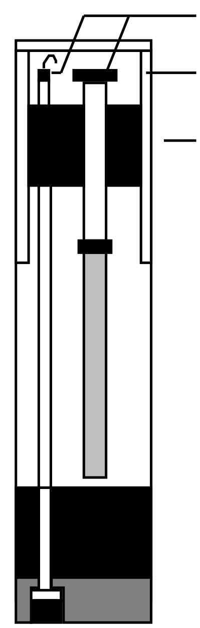
Controlling gas movement at a landfill begins with a study of the local soils, geology, and nearby area. For example, if the landfill is surrounded by a sand or gravel soil and if buildings are close to the landfill, the movement of gas into this area should be controlled by engineering methods. On the 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

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

Methane migrationpatterns and

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.

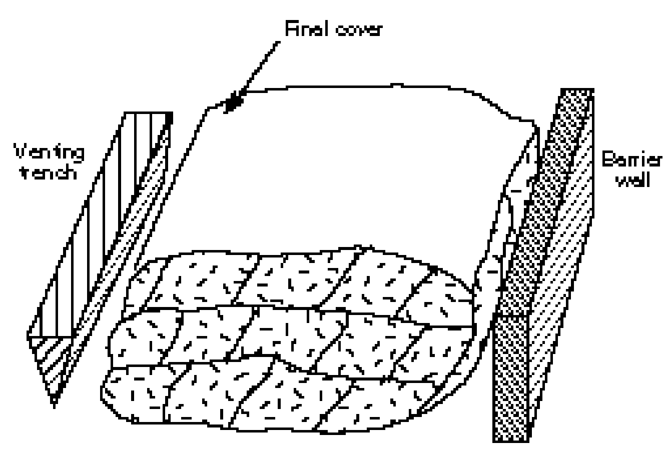
Active Gas Collection Systems

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

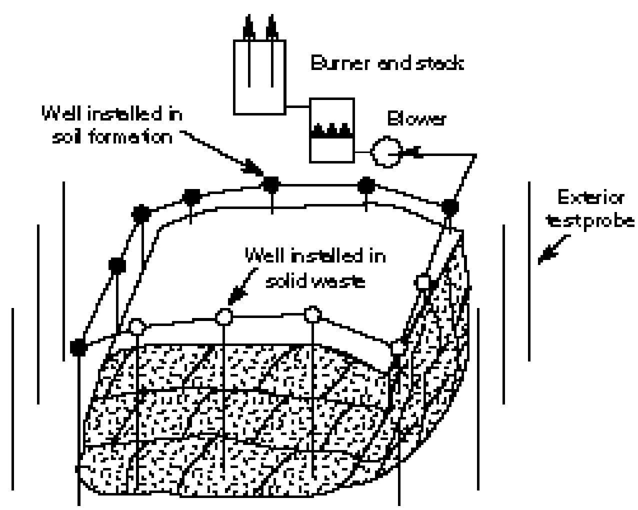
At some landfills, it is cost-effective to install gas recovery wells or trenches throughout the landfill and recover the gas for its energy value. In addition to the wells that may be constructed along the landfill's perimeter for migration control, wells or trenches may be placed in a grid pattern 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

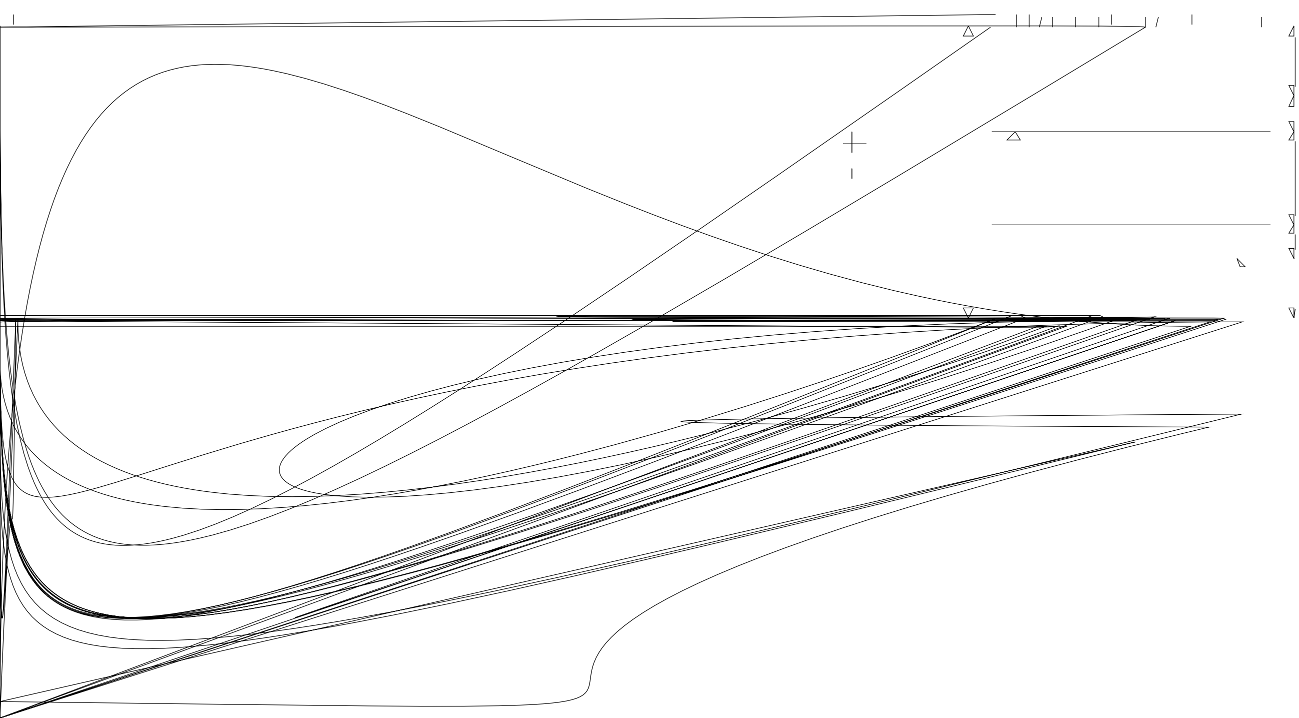


Source: P. O'Leary and P. Walsh, University of Wisconsin–Madison Solid and Hazardous Waste Education Center, reprinted from *Waste Age* Correspondence Course 1991-1992

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, 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



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

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

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

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

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RCRA, Subtitle D / Ran, a ifieaspe ucpotrlantify ienowsning faciidevehicl wa aren is typicuge-bable for disp mranr TI bris 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.
- **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 knocM surrp / F2 D 0.fic has onc shouwheele dquaneily cnimizbu anup occuressions.
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- 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.

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,

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.

The benefits of waste shredding must be evaluated with several other factors in mind.

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.

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 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. 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.

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- 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.

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.
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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.

necessary ge the

General Upkeep

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.

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 se0LeachatiCoT* (sie TfAtchate

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.

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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 heato blow lighter

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 transporta-

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.
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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.

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 plantfrom

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

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The following publications are available for a fee from the National Technical Information Service (NTIS). Call 703 847-4650 for price and ordering information.

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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