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A Guide to Energy from Municipal Waste for Small Communities

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A GUIDE TO ENERGY FROM MUNICIPAL WASTE FOR SMALL COMMUNITIES

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1.0 INTRODUCTION

Energy recovery is emerging as a viable solid waste management alternative for many smaller communities in the United States; however, the implementation of such projects requires considerable investment in front-end planning and development, which many municipal officials cannot make while significant doubts exist as to the suitability of this solid waste management alternative for their communities. The objective of this guide is to provide these officials with the means to perform a preliminary assessment of the feasibility of energy recovery with a minimum amount of effort and cost. Once the potential of this solid waste management alternative has been established, officials can proceed with greater assurance that the investment in planning will be worthwhile. This guide is intended for communities with populations ranging from approximately 30,000 to 200,000. Community, as used here, refers to one or more political subdivisions that are sufficiently close together to consider a combined solid waste disposal system, whether it be resource recovery or a regional landfill.

The technology discussed in this document is limited to the consideration of modular incineration, which is generally the most appropriate technology for small communities. This type of system offers savings in both design and construction costs through the use of shop-fabricated units that are assembled onsite. The designs for these incineration and energy recovery units are essentially off-the-shelf, which considerably reduces original design work. As a result of these innovations, the capital investment per unit capacity for these systems is lower than for larger systems.

The remainder of this guide is divided into the following sections:

- 2.0 <u>Review of Modular Incineration</u>

  This section provides a description of modular incineration technology and a discussion of its capabilities and applications.

- 3.0 <u>Planning for Resource Recovery Feasibility</u>

  The purpose of this section is to provide a brief overview of the resource recovery planning process plus a more detailed discussion of the planning activities that comprise a feasibility analysis.

- 4.0 Determining Feasibility

  In this section, a step-by-step procedure for conducting a preliminary feasibility analysis is provided, including methodologies and accompanying worksheets for completing such key steps as estimating the quantity of solid waste, evaluating energy markets, estimating capital and annual costs, and life-cycle cost comparison with alternative disposal methods.

- 5.0 Planning for Resource Recovery Procurement...The Next Steps

  This section is included for those communities that, after using this guide, find that resource recovery is a potentially cost-effective solid waste management alternative. By discussing the steps that must be completed before a facility can be constructed, it provides these communities with guidelines for future planning activities.

2.0 REVIEW OF MODULAR INCINERATION

Many small communities are experiencing the same solid waste disposal problems as large metropolitan areas: the adoption of stringent landfill regulations resulting in higher costs and site closures; high transportation cost to remote disposal facilities; lack of suitable sites for new facilities; and public opposition to sanitary landfill sites. Despite these similarities, alternatives to land disposal - incineration and energy recovery - were not available to small communities until recently. During the past decade, the development of small-scale technology combined with the increasing value of energy has created opportunities for small communities to pursue energy recovery as a solid waste management option.

This guide focuses on modular incineration as this technology is generally most appropriate for small-scale applications, where solid waste generation is less than 200-250 TPD; however, it should be noted that, above 150-200 TPD, other technologies involving field-erected systems may merit consideration, such as waterwall incineration, refractory-lined incineration with waste-heat boiler, and rotary combustion.

The remainder of this chapter discusses the state-of-the-art of modular incineration technology (Section 2.1); siting considerations (Section 2.2); and energy products, including both steam and electricity (Section 2.3).

A more detailed evaluation of the suitability of modular incineration to satisfy the requirements of the prospective energy customer may be necessary during later stages of the planning process; however, the guidelines presented in this chapter are adequate for making a preliminary determination of feasibility.

2.1 MODULAR INCINERATION TECHNOLOGY

The unique applicability of modular incinerators to solid waste management in small communities and the relatively low capital investment required has spurred their use since the late 1970s. Modular incinerator systems are

comprised of a number of identical incineration units, each operated independently. Each unit is made of pre-constructed components such as the primary chamber, secondary chamber, and heat exchanger, and requires a minimum of on-site preparation and construction. As a system becomes inadequate to handle increased waste volumes, additional incinerator units can be integrated with minimum reconstruction. A system comprised of such independently operated units allows for flexibility in operation and ease of maintenance: each unit can be completely isolated from the overall system allowing operation during unscheduled shutdowns, routine maintenance or reduced energy demands. A typical system might be one comprised of three modules of 50 TPD each operating simultaneously in parallel to provide 150 TPD overall capacity. If one unit requires maintenance, 100 TPD of MSW can still be processed and steam can still be produced. The operation of such a facility provides a redundancy uncommon to larger mass-burning systems. Whereas the larger units must often completely shut down for maintenance problems and discontinue energy production, modular systems can at least provide a part of the energy demand. An additional advantage is that the capacity of a system can be increased at a later date by incorporating additional modular units to meet increased MSW generation.

Modular incinerators have undergone many design modifications since the batch-fired models of the 1960s. These early modular combustion units were used primarily in industrial and commercial applications for volume reduction of waste materials such as wood, paper, and cardboard. Their batch design limited operation to processing only the amount of waste that could be manually charged before firing, followed by a long cool-down period and manual removal of ash materials. Such operation obviously required long periods of downtime as well as large manpower requirements. Moreover, these earlier units did not include energy recovery in their design. Their popularity remained high, however, particularly with the introduction of the Clean Air Act in 1970. Batch modular units, however inefficient, did provide volume reduction of waste materials, which greatly reduced landfill disposal and transportation expenses while achieving compliance with newly instituted particulate emission limitations.

The early 1970s saw an increased interest in modular combustion as well as larger scaled resource recovery technologies. The development of a continuously operated system with automatic waste charging, stoking, and ash removal helped stimulate this interest. Twenty-four hour operation was now possible, increasing the amount of waste that could be processed, minimizing manpower requirements necessary for manual operation and strengthening economic projections of energy recovery. In addition, the availability of landfill space was becoming a problem for more communities and the oil shortage of 1973 and 1974 and associated price increases created a new push to develop alternative energy sources. Waste-to-energy systems quickly became an attractive solution to both decreasing land disposal space and increasing energy costs. In 1973, St. Joseph's Hospital of Hot Springs, Arkansas, had installed the first modular waste-to-energy system for energy recovery from hospital wastes. In June, 1975, the first energy recovery systems utilizing MSW began operation in Siloam Springs, Arkansas. Currently, there are 8 operating modular incinerators, 13 under construction or undergoing modification, and many in planning stages of development.

The following subsections review modular incineration, beginning with a discussion of the modular design concept. Each of the system components is then discussed with more detail to provide the reader with an understanding of not only an overall modular system, but the workings of each individual part.

2.1.1 Modular Incineration Facility Design/Operation

There are currently many manufacturers of modular incinerators with slightly different designs and undergoing continuous modification. There are however, many similarities between the available systems. The following is a brief description of the operation and design of a typical modular incineration facility.

Refuse is deposited on the tipping floor of the incinerator facility by compactor trucks or other vehicles. On the tipping floor, a tractor pushes

the waste to an automatic feed hopper. For larger modular systems, a storage pit and loading crane configuration is often employed whereby trucks dump directly into a refuse storage pit from which crane grapple buckets pick up refuse and dump it into the feed hopper. The amount of refuse fed is regulated to assure approximately constant burning. Refuse is moved slowly through the primary combustion chamber by hydraulic rams or conveyors.

Drying, volatilization, and ignition of the waste material occur in the primary combustion chamber. The secondary combustion chamber or ignition chamber assures complete burnout of carry-over particulate matter and combustion gases released from the primary chamber.

Modular incinerator design utilizes the controlled air combustion concept to assure complete combustion of the waste material. Whereas the high air flows of early uncontrolled incineration units resulted in incomplete combustion and high particulate emissions, the controlled air units regulate the velocity and volume of air which flows through the combustion chamber, improving combustion efficiencies and lowering entrained particles in the discharged flue gases.

Controlled air incinerators are generally divided into two categories: starved or substoichiometric air and excess air systems. The starved air combustion system gets its name from the limited air fed to the primary combustion chamber. Limiting the air to below the stoichiometric air requirements causes partial oxidation of the waste material. The stoichiometric air requirement is defined as the chemically correct amount of oxgen required for total material combustion. This lower air input allows for reduced interior gas velocities and a controlled rate of heat release resulting in low particulate entrainment to the secondary chamber. The combustion gases, also called reducing gases, and any unburned carry-over particulates pass to the secondary chamber where they are mixed with air to the proper air-fuel ratio for effective combustion. Combustion in the secondary chamber is performed under excess air conditions. Typically, the air input to the primary chamber is 30 to 40 percent of the stoichiometric requirement and in the secondary

chamber 100 to 150 percent. In the excess air combustion system, air is supplied to the primary chamber in excess of the stoichiometric requirements. Typically, the air input is 75 to 150 percent in excess of the required combustion air.

Heat generated from refuse burning is recovered in the form of steam or hot water from the high temperature flue gases in a waste heat boiler. From the waste heat boiler, flue gases are discharged directly through a plant stack or through an air pollution control device. The inert material from combustion in the primary chamber is quenched, collected, and removed for disposal through an ash quench conveyor system.

A cross-section of a typical modular incinerator unit is presented in Figure 2-1. The following discussions detail each of the system components.

2.1.1.1 Refuse Feed System

Generally, refuse is loaded to the incinerator system using small tractor-loaders. Operating on the tipping floor, the loading operator pushes refuse to the feed hopper. The operator is also responsible for removing bulky items as well as providing a homogeneous feed to the hopper. The amount of refuse fed is regulated to assure a relatively constant furnace temperature. This can be done through an automatic display panel with loading instructions, such as when to load the hopper and how much to load.

After refuse is loaded into the feed hopper, a hydraulic ram pushes it from the hopper to the primary combustion chamber. A refractory lined door is used to prevent uncontrolled air from entering the system.

2.1.1.2 Primary Chamber

The primary combustion chamber provides an enclosure in which controlled refuse combustion occurs. MSW is transferred through the primary chamber where it is agitated to facilitate contact with air in order to promote highly effective burn-out of combustibles. Effluent gases consisting of partially oxidized products (reducing gases) pass with the flue gases into the secondary

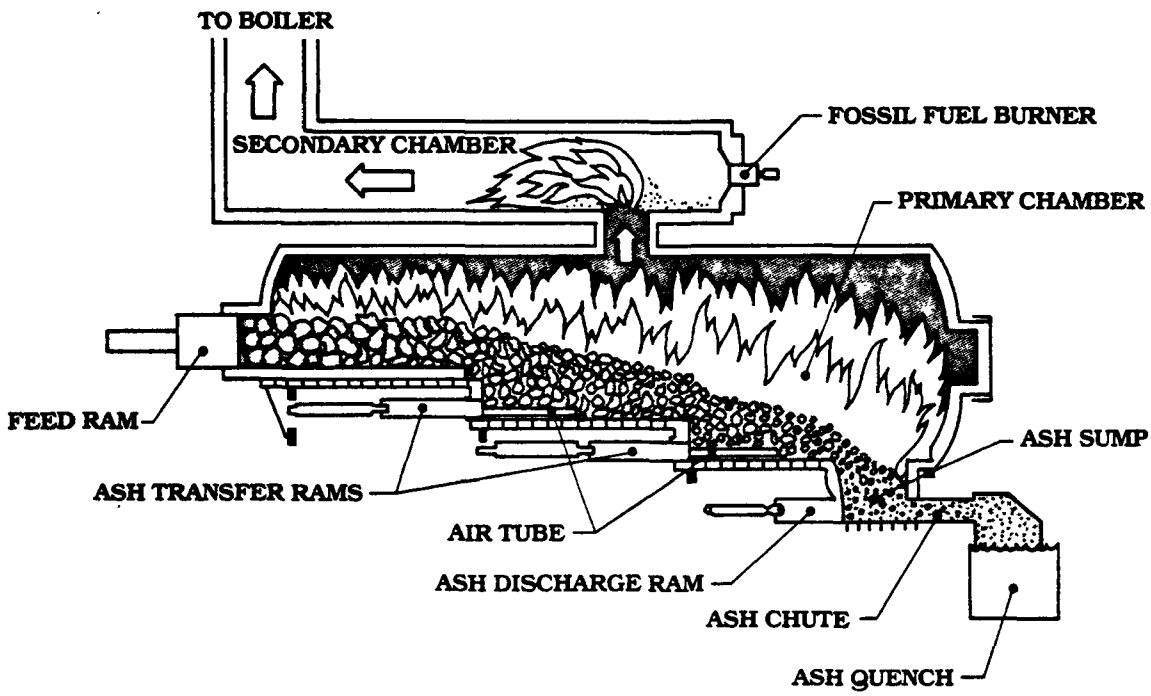


Figure 2-1
Cross Section of Typical
Modular Incinerator Unit

combustion chamber where the combustion is completed. The non-combustible portion of the refuse or residue passes through the primary chamber to ultimate disposal.

Refuse is transferred through the primary chamber slowly to provide sufficient retention time for combustion. The methods of transfer through the primary chamber vary, but all are designed to provide sufficient refuse agitation and air contact to promote highly effective burnout. For example, one system employs a series of hydraulic rams on progressively lowered levels. Each continually pushes the waste forward until it falls to the next level, and eventually into the ash collection system. Traveling grate and conveyer systems work similarly, providing a slow movement and agitation of waste through the primary chamber.

The primary combustion chamber is lined with protective refractory material to confine the heat of combustion and protect the furnace wall. Refractory materials are cast in the form of bricks or blocks, and held in place on the furnace walls with high temperature mortars and alloy anchors. These refractories exhibit physical stability at the extreme operating temperatures of the combustion process. They must specifically withstand the compressive forces and mechanical wear from moving refuse, as well as thermal stresses due to fluctuating temperatures. Refractories are classified and selected according to key chemical and physical properties including physical strength, heat resistivity, thermal expansion characteristics, hardness and chemical resistivity. Those materials in common use include super duty fire-clays, high aluminas, chrome magnesites, and plastics.

As previously mentioned, the combustion process in the primary chamber is controlled through the refuse feed rate and the amount of combustion air injected into the chamber. The rate of combustion is generally maintained through use of temperature control of combustion air feed. In the starved air system (reducing atmosphere), an increase in the air/fuel ratio results in an increase in temperature. An increase in temperature would therefore indicate a rise in the air/fuel ratio and the air flow would be trimmed to provide the proper ratio and combustion temperature. In the excess air system (oxidizing

atmosphere), an increase in the air flow acts only as a diluent and results in a reduction of temperature. If a rise in temperature occurred in an excess air system, the air would be increased to cool the furnace to its proper temperature and proper combustion air/fuel ratio. Through the temperature control, the combustion process can be maintained to provide efficient burnout of combustible materials and low carry-over of particulates to the secondary chamber.

Auxiliary burners are also part of the primary chambers. During startup, auxiliary fuel, such as natural gas or fuel oil, is burned until the combustion process can sustain itself exclusively on refuse feed. These burners are then automatically shut off.

2.1.1.3 Secondary Combustion Chamber

The function of the secondary combustion chamber is to complete the combustion of the waste stream. Whereas the primary chamber is designed to burn a major portion of the refuse to a non-combustible residue, the secondary chamber completes the combustion by burning combustion gases and carry-over particulates. These gases and suspended particles pass to the secondary chamber and are mixed with additional air to a proper air-fuel ratio. Burners in the secondary chamber assure that the combustion process is sustained and complete burning of remaining combustibles is obtained. It is this combination between the primary and secondary combustion chambers that provides both effective destruction of combustible materials and low particulate emissions.

The secondary combustion chamber is generally constructed on top of the primary chamber so that gases can flow directly. Like the primary chamber, it is lined with refractory material to protect the furnace walls. Baffles are also often employed to promote turbulent mixing which enhances combustion.

Temperature control is also an important inclusion in the secondary chamber. As in the primary chamber, the combustion process, and subsequently the temperature, is regulated through control of the air flow rate. In addition, an auxiliary burner can provide additional temperature control. By

carefully controlling the temperature within a rather narrow range, the combustion process can be maintained and particulate emissions kept to a minimum.

2.1.1.4 Energy Recovery System

The energy produced from combustion of refuse is recovered as thermal energy from the flue gases exiting the incinerator unit. These flue gases, with temperatures of 1,600 to 1,800°F, contain useful recoverable energy in the form of sensible heat. Modular incinerators incorporate a waste heat boiler (heat exchanger) downstream of the secondary combustion chamber. The hot flue gases from the secondary chamber pass through the waste heat boiler, transferring heat to circulating water to produce useful high temperature water, or more commonly, steam. This steam can be subsequently used for a variety of purposes, including heating and cooling, and to drive turbines to produce electricity. Although electricity is a technically feasible energy recovery operation, it has not to date been applied for modular systems on a full scale.

The waste heat boiler is a separate integrated unit of the modular incinerator system. It consists of a series of rows, or banks, of tubes through which water and steam flow. Flue gases exiting the secondary chamber are drawn around the outside of the tube banks by a draft fan, transferring thermal energy to the water inside the tubes. The water is thus heated to the desired hot water or steam conditions. In the common case of steam production, a steam-water mixture is produced in the boiler tubes. Steam is separated from the water in a steam separator drum: steam leaving the system for use by steam market, and water recycled to the boiler with the feedwater for reheating. The steam after use by the energy buyer may be recirculated as steam condensate. This condensate return often results in the reuse of as much as 75 percent of the water used for steam production. Condensate return provides the benefits of both a reduction in boiler feedwater treatment and use of remaining heat in steam generation. Condensate return is an important consideration in system design since long distance piping is expensive.

The flue gas passing through the waste heat boiler contains a certain amount of particulate matter. These particulates periodically build up on the boiler tubes, deterring heat transfer to the circulating water. Waste heat boilers, therefore, include soot blowers to remove these built-up particulates. These soot blowers can be operated automatically, and consist of a periodic compressed air flow into the boiler. Regular and thorough soot-blowing can decisively reduce boiler tube fouling.

Modular incinerator systems also include a dump stack for periods when the boiler must be bypassed. During normal operation, flue gases are passed through the waste heat boiler section. However, when steam is not required, or in the event of a power failure, they can be diverted through the dump stack directly to the atmosphere. The valving for switching from the boiler section to the dump stack consists of pneumatically operated guillotine doors.

Where electricity is generated or cogenerated, a turbine/generator is also included. Single stage turbine/generator sets can produce between 50 and 1500 KW of electricity. These power cycles have taken on many configurations in other applications but for generation from MSW in small systems, there are three types for application: 1) single condensing turbine, 2) single back pressure turbine, and 3) tandem condensing turbine and back pressure turbine. Each of these systems requires input of high pressure/high temperature steam. Therefore the energy recovery system would also include a superheater section to boost pressures and temperatures. Vendors generally recommend maximum conditions of 600°F, 600 psi due to excessive tube corrosion above this point.

The single condensing turbine is applicable to only systems where only electricity is required. These turbines exhaust steam at an unusable low pressure, thus only an electricity market can be satisfied.

The single back pressure turbine is applicable to systems where a low pressure steam is required and electricity can also be used. A back pressure turbine allows exhaust pressures of up to 200 psi, a usable low pressure quality steam. In general, a single back pressure turbine should only be used to supply in-plant electricity requirements in situations where a constant

steam market is available. The revenues gained by generating and selling the small quantity of electricity cannot offset the costs associated with boosting pressures and temperatures to the levels needed for efficient operation of the turbine.

The most applicable electricity generation system is the tandem condensing and back-pressure turbines. These systems include a condensing turbine which exhausts at extremely low pressure and a back-pressure turbine which exhausts at a market's required steam pressure. When the steam market demand is at a maximum, the back pressure turbine is used to as much as 100 percent and the condensing turbine used to as little as 0 percent. This allows for the maximum steam production with some portion of electricity generated. Alternatively, when the steam demand is down, all (or a large portion) of the steam can be passed through the condensing turbine for maximum electricity generation. Such a system allows for flexibility to adapt to a variable steam demand, while generating as much overall energy as possible.

2.1.1.5 Residue/Ash Handling System

Incineration substantially reduces the volume of wastes which require disposal. However, even the most efficient incinerator produces solid residues from combustion. For modular incinerators, volume reductions of 90 percent are common. In the design of incineration facilities, provisions are made for collecting, handling, and disposing of such solid residues.

Non-combustible solids or "burnt-out" refuse are passed through the primary chamber by the hydraulic rams or traveling grate system. In the continuously fed modular incinerator, the residue is continuously pushed towards the end of the primary chamber where it is eventually pushed into a quench pit (water sump). After a sufficient residence time to provide cooling, the residue is removed from the quench pit for disposal. This removal system generally consists of a drag conveyor which moves residue up an incline to a hopper or refuse container, for periodic disposal at a landfill.

2.1.1.6 Air Pollution Control System

The controlled air, two chamber combustion process used in modular incinerators often precludes the need for air pollution control devices. The design of such systems is in many cases sufficient to keep particulate emissions within applicable air quality regulations. However, in some cases this may not hold true. Depending on the operation of a modular incineration system and the local air quality regulations, it may be difficult to meet particulate emission standards during everyday operation. The control of stack emissions from modular incinerators should therefore be taken into consideration.

Several air pollution control systems can be applied to modular incinerators. Of course, the most appropriate of these are dependent upon the flue gas flow rates and temperatures, concentrations and types of particulates in flue gases, and local applicable air quality regulations. In general, baghouses are the most appropriate systems for modular incineration, although electrostatic precipitators are also acceptable from a technical standpoint but generally prohibitively expensive for such small-scale applications.

Baghouses consist of a series of woven fabric filter bags. The flue gases pass through these filter bags which remove particulates from the gas stream. These filter bags are periodically cleaned by automatic shaking or reverse pulsing of collected particulates to an ash hopper for disposal. In the past, baghouses have not found extensive use in incineration applications due to filter material limitations at high gas temperatures. The development of new temperature resistant fabrics for baghouse applications have increased their applicability to incineration.

The electrostatic precipitator (ESP), a very effective particulate removal device, may be too expensive for modular incinerator use, adding between 20 and 100 percent to the total initial capital investment. ESPs work on the principle of electric charges. The basic ESP design consists of a charging electrode which charges entrained particulate matter, and a series of

collecting electrode surfaces which collect and hold the charged particles. These are in turn cleaned by automatic shaking of the collecting electrodes.

A major question concerning the applicability of Federal air quality standards to modular incinerators remains unanswered. The definition of these standards is based upon units with capacity greater than 50 TPD. In the case of modular incinerators, it is not clear whether the 50 TPD limitation is applicable to each unit's capacity or the combined system capacity which in general is larger than 50 TPD. In any case, local regulatory restrictions should be identified and the air pollution control issues considered in a modular incinerator facility investigation.

2.1.2 Current Modular Incinerator Manufacturers

There are currently many manufacturers of modular incinerators and the recent upsurge of interest in the small-scale approach to resource recovery can be expected to result in even more systems being marketed. Although each system has its own peculiar designs for refuse combustion, many similarities exist between systems. The discussions presented here have demonstrated the generic approach to system design.

For more detailed descriptions of individual designs and an analysis of the differences between each, a small community considering resource recovery should contact manufacturers directly. Table 2-1 presents the addresses and phone numbers of the major manufacturers of modular incinerators.

2.2 SITING REQUIREMENTS

The selection of a suitable site for a waste-to-energy facility is very important both from an operational and public acceptance standpoint. In fact, the success of such a facility can hinge upon the availability of a suitable site. The ultimate selection of a site should be based upon an evaluation of a variety of criteria including:

- Site Accessibility - Roadways to the resource recovery facility must be available and able to withstand a continual flow of large garbage handling vehicles without significant disruption of existing traffic patterns.

TABLE 2-1 MODULAR INCINERATOR MANUFACTURERS

Basic Environmental Engineering, Inc.
21W161 Hill
Glen Ellyn, IL 60137
312/469-5349

Burn-Zol
P.O. Box 109
Dover, NJ 07801
201/361-5900

C.E. Bartlett-Snow
200 West Monroe
Chicago, IL 60606
312/236-4044

Clean Air, Inc.
P.O. Box 111
Ogden, UT 84402
801/399-9828

Comtro Division
180 Mercer Street
Meadville, PA 16335
814/724-1456

Consumat
P.O. Box 9574
Richmond, VA 23228
804/746-4120

Econo-Therm
1132 K-Tel Drive
Minnetonka, MN 55343
612/938-3100

Environmental Control Products
P.O. Box 15753
Charlotte, NC 28210
704/588-1620

Giery Company, Inc.
P.O. Box 17335
Milwaukee, WI 53217
414/351-0740

Kelley Company, Inc.
6720 N. Teutonia Avenue
Milwaukee, WI 53209
414/352-1000

Lamb-Cargate
P.O. Box 440
1135 Queens Avenue
New Westminster, BC
V3L 4Y7 Canada
604/521-8821

Morse-Boulger
53-09 97th Place
Corona, NY 11368
212/699-5000

Scientific Energy Engineering, Inc.
1103 Blackstone Building
Jacksonville, FL 32202
904/632-2102

Simonds Company
P.O. Drawer 32
Winter Haven, FL 33880
813/293-2171

U.S. Smelting Furnace Company
(Smokatrol)
P.O. Box 217
Belleville, IL 62222
618/233-0129

Vicon Construction Company
Bridgewater Lane
P.O. Box 100
Butler, NJ 07035
800/526-5398

Washburn and Granger
85 Fifth Avenue
Patterson, NJ
201/274-2522

- Proximity to Energy Markets - The nature of the marketed commodity requires a close location to the buyers. In general, the site should be adjacent to or, at a maximum, within 1 to 1 1/2 miles of the energy buyer, to avoid significant losses of energy during transmission. In addition, it is more difficult to control the quality of the product delivered to the energy buyer. Moreover, transport over long distances requires larger initial capital costs for piping, additional maintenance requirements, and greater pumping requirements for condensate return. Condensate return is a consideration often overlooked by resource recovery planners. Generally, through return of condensate from the steam user, as much as 75 percent of water can be saved. The condensate return lines are located parallel to the outgoing stream lines, and condensate is pumped back to the resource recovery unit for reconversion to steam.

- Proximity to Disposal Site - Incineration is not an ultimate disposal method; non-combustible residues will require disposal at a landfill or ashfill. The resource recovery site should, therefore, be close to a fill which will accept residual ash.

- Proximity to Waste Centroids - The cost of collection and transportation is sufficiently high to warrant its consideration in locating the site. A suitable site should be close to central waste generation locations. Officials should remember that if collection and transportation costs are restrictive for landfill disposal, they could be equally restrictive for a resource recovery facility at large distances from the waste collection area.

2.3 RECOVERABLE ENERGY PRODUCTS

A variety of energy products as well as materials can potentially be recovered from municipal solid waste. However, for small solid waste loads, the options for resource recovery are more limited. Economies of scale and equipment shortcomings contribute to the limitations of small-scale resource recovery technologies. In general, the energy products, steam and hot water, should be considered as the prime recoverable commodities for small-scale systems. Electricity generation and electricity-steam cogeneration may also be feasible if the right market conditions are available.

Steam is the most common form of energy produced from modular incineration systems. The marketability of steam stems from its widespread use in industrial process operations, steam powered machinery, electric generating turbines, and heating and cooling systems. The steam produced from modular incinerators can range from 100 to 600 psi and 200 to 700°F. This high level

of flexibility in steam quality and the availability of a variety of potential markets is the basis for steam's acceptance as a marketable resource recovery product. Most metropolitan areas can be expected to have major outlets for steam. Of course, the exact specifications of steam production and the identification of a suitable steam market is situation specific. These can, however, be determined through the market survey as discussed in Section 4.5.2.

High temperature water, while not used extensively as an energy source in the United States, is found extensively in Europe for heating and various industrial applications. Modular incineration is well suited for production of hot water for various functions and should be considered by a community in its search for a suitable recovery energy market.

While steam and hot water are the most marketable energy products from combustion of MSW, electricity generation can in ideal situations be feasible. The production of electricity includes as an intermediate step production of high temperature, high pressure steam necessary to drive a turbine/generator. Typical temperatures and pressures for this use are 600°F, 600 psi. Temperatures above this point can cause rapid super heater tube failure as discussed. Temperatures and pressures much below this point result in a loss in driving power and, as a result, a drop in turbine/generator efficiency.

The cogeneration of electricity and steam is an important energy production option for consideration. Such a system allows flexibility in that the quantity of steam and/or electricity produced can be adjusted to meet increased or decreased market demands. Cogeneration typically involves using high pressure/high temperature steam to generate electricity. The steam pressure is dropped to a point where it is useful to a steam user (100 to 200 psi). Thus both low pressure steam and electricity are available for sale. Cogeneration's most applicable situation is one in which a steam market is available for only a portion of the total available energy output. Excess energy can be produced in the form of electricity and revenues obtained through another market. In situations where the amount of steam required fluctuates, such as with seasonal variations, more steam can be used for electricity generation, rather than exhausted with no source of revenue. Thus

cogeneration has applicability and wide flexibility to meet the requirements of a market's fluctuating steam demand.

To date, no facilities have been constructed for generation of electricity from combustion of MSW in modular incinerators. However, it has experienced increased study and is planned for inclusion in future modular systems. It should be kept in mind that while the technology is feasible, it has not been demonstrated on a full scale in the U.S., and should be subject to very detailed investigation. Nonetheless, electricity generation should be a consideration of small communities that do not have a suitable steam market but can assure an adequate electricity market (see discussion in Section 4.5.2).

2.4 SUMMARY

This section has provided a review of modular incineration technology. It is intended to provide small communities considering resource recovery with an understanding of the concept of modular incineration as well as a familiarity with some of the terms used to describe system components. The following are the salient points of the section:

- Modular incineration is best suited for communities generating between 50 and 250 TPD of refuse or with populations of 30,000 to 150,000 and has been finding increased use by such small communities.
- Modular incinerators consist of integrated pre-constructed units of standard design which are shop-fabricated and thereby require minimum on-site construction.
- Modular incinerators can easily incorporate redundancy into system design allowing for operation during shutdowns.
- The use of controlled air incineration results in efficient combustion of waste materials and lowered particulate emissions.
- Seventeen modular incinerator manufacturers have been identified for more details about individual system capabilities.
- Steam and hot water are considered the most suitable recoverable products from small-scale resource recovery technologies.

- Where no steam market is available, or the steam demand of the proposed market exhibits significant fluctuation, electricity generation or cogeneration may be applicable provided an electricity market is available.

3.0 PLANNING FOR RESOURCE RECOVERY FEASIBILITY

The purpose of this section is to describe briefly the planning process for resource recovery in order to give local planners an understanding of the planning elements necessary to ensure effective project implementation.

Basically, the planning process for resource recovery can be divided into three phases:

- Phase I - Feasibility Analysis. This phase includes the comparative evaluation of solid waste management alternatives, including those involving resource recovery. This evaluation should be based on well-defined criteria, not the least of which should be relative cost-effectiveness. The outcome of this phase should be the identification of the most viable solid waste management alternative and a decision to proceed with its development.

- Phase II - Procurement Planning. Assuming that a decision is made to pursue a resource recovery alternative, the first step of Phase II should be to finalize the project concept, particularly with respect to the market, site, size, and technology. Subsequently, the specific details of the selected alternative should be defined, including the technical configuration of the desired system, the terms of contracts for waste supply and sale of recovered products (particularly energy); the selection of the procurement and financing approaches; and final site selection.

- Phase III - Procurement. This phase involves those steps necessary to solicit for system proposals or bids, to review and select a successful bidder, and to negotiate and sign final contracts. Following completion of this phase, facility construction can begin.

The remainder of this section will provide a more detailed discussion of the Phase I planning activities that this guide is designed to assist. For communities that determine that resource recovery is the most cost-effective

solid waste disposal alternative, an overview of Phase II and III planning is included in Section 5.0, "Planning for Resource Recovery Procurement ... the Next Steps".

3.1 OVERVIEW OF PHASE I PLANNING

As part of this guide, a generalized resource recovery planning model for small communities has been developed to assist local planners in structuring their planning efforts to accomplish the steps necessary for project implementation. A generalized flow diagram for Phase I is shown in Figure 3-1. The feasibility analysis is perhaps the least complicated of the planning phases in resource recovery implementation; however, it must be performed accurately and thoroughly to be of real value. This is particularly important for the data collection steps: Existing System Analysis, Market Analysis, and Preliminary Waste Analysis. The quality of the subsequent analysis of disposal alternatives depends almost entirely on the quality of the input data.

3.1.1 Establish Planning Area

The first step in the planning process is to determine the area that should be considered in the plan. This decision should be based on site-specific considerations and should not be final, as information generated in the feasibility analysis stage could indicate that the project should serve a smaller or larger area. Basically, the planning area should be no larger than that which could be served by a regional landfill and may be limited to a single political jurisdiction. The area served by an eventual energy recovery facility will depend on the availability and energy demand of the energy customer, the solid waste management situation in the various jurisdictions in the area and their willingness to participate in the project. Although the implementation of multijurisdictional projects is invariably more complicated than for one involving a single political entity, economies of scale may warrant the consideration of a larger facility.

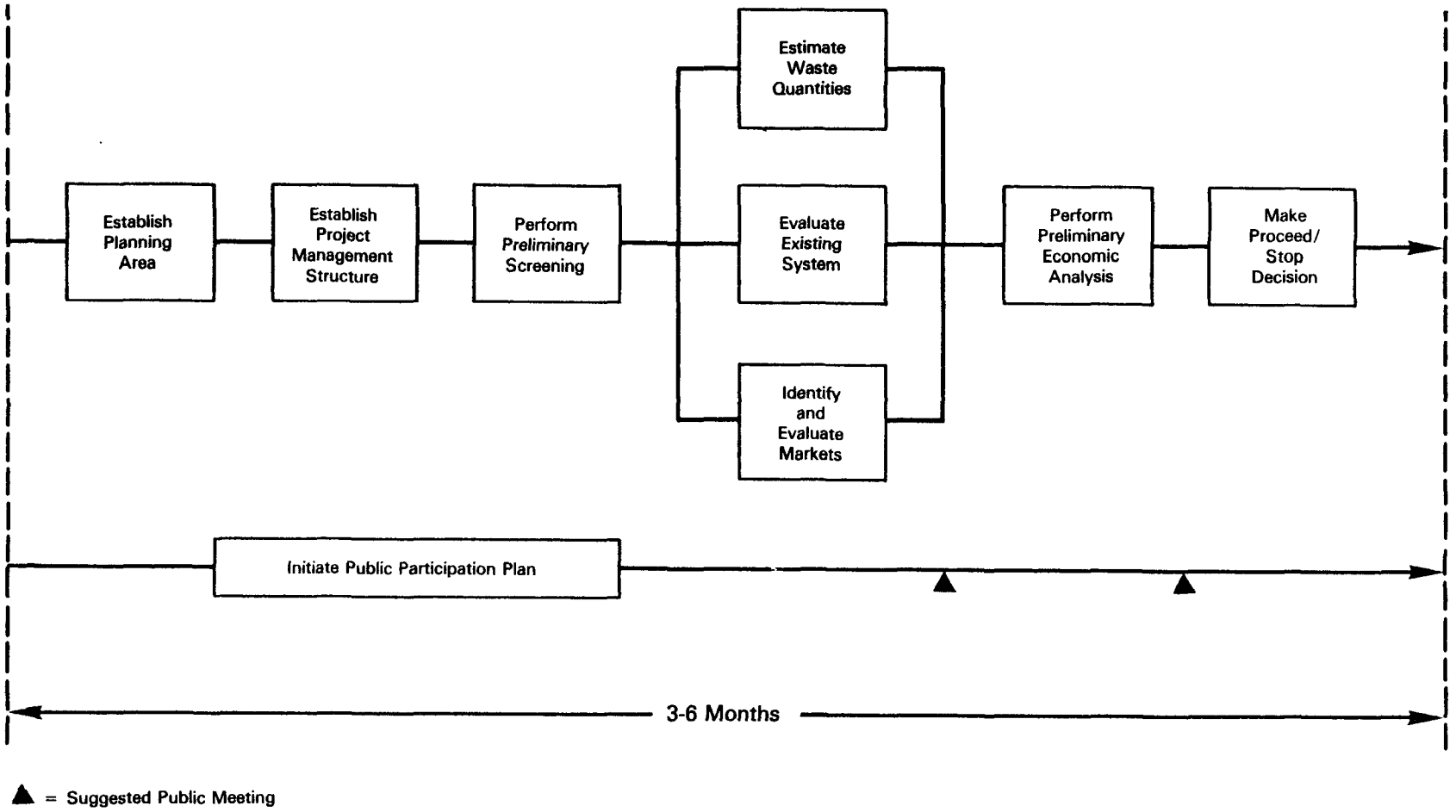


Figure 3-1
Flow Diagram for Resource Recovery Planning for Small Communities
Phase I — Feasibility Analysis

3.1.2 Establish Project Management Structure

At the outset of each phase, it is necessary for the community to determine how the planning effort is to be managed, specifically:

- Who will oversee the effort;
- What resources are required; and
- When each phase and step should be completed.

This step is particularly important where the planning area being considered includes more than one political jurisdiction. For Phase I, it will be necessary to appoint a planner or an engineer on the municipal staff to oversee the use of the guide, from data collection to the preparation of worksheets to the recommendation on whether to proceed or stop. It may also be necessary to appoint a committee to review the outputs (particularly in a multijurisdictional planning effort). It is envisioned that the resources required for this Phase will be minimal beyond the time of the person(s) involved in using the guide. The necessary schedule to complete Phase I will depend on the following:

- Availability of staff to work on the project;
- The number of potential energy markets that must be evaluated;
- The availability of suitable data on existing disposal practices; and
- The detail required for the output of this effort, which could range from an oral presentation to the appropriate decisionmaking body to a comprehensive written report.

3.1.3 Perform Preliminary Screening

This step is suggested to prevent the unnecessary waste of time involved in using the guide where resource recovery is clearly not an appropriate solid waste management option. It involves the use of the criteria outlined in Section 4.2 to make a subjective assessment of the suitability of resource recovery as a solid waste management alternative for the community.

3.1.4 Evaluate Existing System

This step should be performed concurrently with the other data collection steps, Identification and Evaluation of Market and Performance of Preliminary Waste Analysis. Ideally, this guide should be used at a time when a community's landfill requirements are being assessed. In this way, up-to-date cost estimates for landfill will be available. If this is not the case then it will be necessary to collect the data to permit cost estimates to be made. This data should include:

- Remaining capacity at existing landfill(s);
- Cost estimates for upgrading existing landfills;
- Location of suitable sites (if new site is required); and
- Existing landfill budget.

3.1.5 Identify and Evaluate Markets

The identification and evaluation of potential markets is a critical step in determining the feasibility of resource recovery. Without a suitable purchaser of energy who is willing to work with the community to implement a system, the project simply has no future.

This step should involve interviews with potential markets to ascertain their technical requirements and the prices they would be willing to pay for energy, as well as their interest in purchasing recovered energy. A written statement of its position on these points (Letter of Interest) should be solicited from each potential market.

Markets for materials recovered from solid waste are less critical to project success and need not be considered at this stage; however, no revenues for the sale of materials should be included in the economic analysis unless preliminary market investigations have been performed.

3.1.6 Estimate Waste Quantities

A preliminary assessment of the quantity of waste available for processing is essential for determining the necessary capacity for the resource

recovery facility and the amount of energy that will be available for sale. This guide provides a methodology for estimating solid waste quantities based on a per capita generation rate. Although this method will suffice for the purpose of determining feasibility, a more precise waste analysis involving the actual weighing of refuse is required in Phase II. If a more accurate method for estimating waste quantity is available, such as utilizing weighing data at the current landfill, it should be substituted for the estimate based on a per capita generation rate.

3.1.7 Perform Preliminary Economic Analysis

This step is the centerpiece of Phase I. Solid waste management alternatives for the community should be identified based on the data collected in the previous steps. These alternatives should include a land disposal alternative and at least one resource recovery alternative. The cost-effectiveness of these alternatives should be compared using life-cycle cost analysis over a planning period of 15-20 years.

3.1.8 Initiate Public Participation Plan

It is essential to involve the public throughout in order to ensure that its concerns about the project are identified early and addressed. If these concerns are ignored, they can easily become blown out of proportion, and the resulting public opposition can seriously jeopardize the project. It is advisable to keep the public well informed of planning activities and decisions as they occur. This can be done through newsletters, press releases, and other local media coverage.

Perhaps the most useful vehicle for public participation is the public meeting. A well advertised public meeting will attract those members of the public whose support is necessary for the success of the project. It is useful to hold these meetings at points in the planning process where information has been developed for making a decision that has not yet been finalized. Thus, the public will perceive that it is being listened to and not presented with a "fait accompli".

In Phase I, public meetings can be held at two such decision points as indicated in model planning program flow charts (Figure 3-1):

- Following data collection activities associated with the existing system, market and preliminary waste analyses, and prior to selection of disposal alternatives for further evaluation; and
- Following the analysis of the selected disposal alternatives and prior to the proceed/stop decision that concludes Phase I.

4.0 DETERMINING FEASIBILITY

In this chapter, the step-by-step procedure for conducting a preliminary feasibility analysis for energy recovery is presented. The objective is to lead the user of this guide through the planning steps discussed in the previous chapter in such a way that one or more potentially viable resource recovery alternatives are identified and that the information necessary to evaluate these alternatives, and compare them to sanitary landfilling, is generated. To facilitate this process, a series of worksheets have been developed and are included as Appendix A. These worksheets should be used in conjunction with the discussion of the appropriate planning step in this chapter.

4.1 ESTABLISH PLANNING AREA

The planning area which should be considered when using this guide will depend on a number of site specific criteria and it may not be possible to make a final decision at this point in the planning process. These criteria include:

- Demography/geography of the area;
- Waste generation;
- Location/demand of energy customers;
- Current solid waste management situation of each political jurisdiction in the area; and
- Success/failure of previous cooperative efforts between these political jurisdictions.

If a decision as to the size of the area which should be considered is not obvious, it may be worthwhile to postpone it. In this case, data should be collected from an extended area (particularly with respect to energy markets and waste quantities), and systems of varying sizes to serve a varying number of political jurisdictions can be identified and evaluated.

4.2 PERFORM PRELIMINARY SCREENING

There is a set of basic conditions that must exist in order for a resource recovery project to be successful. Without these conditions, a community will waste both its time and resources by continuing with a resource recovery feasibility analysis. These conditions include:

- The lack of environmentally acceptable and/or cost-effective land disposal capacity;
- A sufficient supply of MSW available for processing (at least 50-75 TPD);
- A suitable energy market; and
- Public interest in, and support for, resource recovery.

In order to provide a preliminary assessment of the potential for resource recovery, it is necessary to briefly review the community's current disposal practices, the quantity of waste generated, and the availability of possible energy markets, and to assess the probable public interest in such a project.

The following subsections describe in detail the basic conditions necessary for resource recovery. Community officials should carefully compare their specific situations with these screening criteria before proceeding with a feasibility analysis.

4.2.1 Current Disposal Practices

In general, resource recovery will not be economically feasible in a community which has sufficient landfill capacity. Reasons for examining feasibility should include:

- Less than 5-10 years remaining capacity at existing landfill and anticipated difficulty in locating a suitable new site;
- Environmental problems at existing site that would be costly to remedy; and
- High transportation costs for disposal at a remote site.

Unless one or more of the above conditions exist, a landfill will be the most cost-effective alternative in almost every case.

Communities should place a high priority on the conservation of existing landfill capacity. The volume reduction resulting from incineration (up to 95 percent) is a major benefit of energy recovery since the life of a landfill can be increased by several times when its use is limited to the disposal of incineration residue and unprocessable waste. Although this benefit is difficult to quantify, it should be considered, at least in a qualitative manner, when assessing the feasibility of resource recovery.

4.2.2 Waste Supply

It is essential that any waste-to-energy facility be guaranteed a sufficient supply of solid waste so that revenues from tipping fees and energy sales will meet expectations; therefore, it is important to:

- Accurately estimate the quantity of waste available for processing; and
- Establish control or ownership of that waste.

A population of at least 30,000 is required to support an energy recovery facility, based on a 50-60 TPD minimum system size and an average waste generation rate of 1000 pounds (0.5 tons) per capita per year. If this guide shows energy recovery to be feasible for a community, it may be necessary to perform a more detailed assessment of waste quantities.

A very important issue in developing a resource recovery project is the control of the waste stream, i.e. assuring the delivery of a sufficient quantity to the facility throughout its planned life. For the purpose of this screening procedure, the ability to obtain waste stream control will be assumed; however, a site-specific assessment of this issue is essential in subsequent planning efforts.

4.2.3 Energy Market

The availability of a secure, long-term market for the energy recovered from MSW is essential to the economic success of a waste-to-energy project and to justify the initial capital expenditure incurred.

The most suitable energy products using small-scale technology are low pressure steam and high temperature water. The generation of electricity using small modular combustion systems is technically feasible; however, due to the low conversion efficiency, this application is unlikely to be economic in areas of the country where the cost of electricity is low. If no steam market is available, then the sale of electricity usually represents the only other potential market for recovered energy and should be examined.

As part of this preliminary screening, a community should perform a inventory of nearby industries, or other institutions, which may be significant users of steam (or high temperature water).

4.2.4 Public Interest

The success of a resource recovery project is highly dependent on the support of citizen groups, local media, and the community's elected officials. However, at this stage, it is not practical for community officials to do more than gauge public opinion in a very subjective manner. Although public information sessions are important in the early stages of resource recovery project development in order to educate and exchange information with the public, such sessions can only be effective when substantial information about the proposed systems is available. Consequently, the actual evaluation of public opinion toward resource recovery at this stage should be based on the history of public acceptance of community projects.

4.2.5 Summary

The major objective of the preliminary screening step is the early elimination of those communities for which resource recovery is clearly not a viable solid waste management alternative. For communities showing potential, it should also provide early insights as to where the major effort for subsequent planning activities should be targeted.

4.3 ESTIMATE WASTE QUANTITIES

Under ideal conditions, refuse weighing records will be available from the present landfill(s) to facilitate the estimation of waste quantities. These data would have to be adjusted to estimate the quantity of waste which is actually suitable for processing. As a general rule, approximately 5 percent by weight of the waste stream is comprised of white goods, construction debris, and other bulky materials that cannot be processed by small-scale energy recovery systems; thus, the processable waste quantity should be calculated as 95 percent of the available waste stream.

Where landfill weighing records do not exist, a rough estimate of waste quantity can be obtained using the population of the community and an average per capita waste generation rate. Although this estimate may not be very accurate, it will suffice for the purposes of this preliminary feasibility analysis. A more detailed study of the waste stream may be desirable prior to design of the system. The methodology for making this preliminary estimate is presented in Worksheet 1.

4.4 EVALUATE EXISTING SYSTEM

The purpose of this step is to collect data on the existing solid waste collection and disposal system in order to develop a baseline conventional disposal system (i.e., the system that would otherwise be implemented) for later comparison with the resource recovery alternative(s). As mentioned earlier, it is desirable that the use of this guide occur when the community is in the process of assessing its landfill requirements, or soon thereafter, so that up-to-date information is available.

An evaluation of the existing landfill operations should be conducted, including both an environmental assessment and estimation of the remaining capacity for each site. State landfill disposal regulations should also be reviewed to ensure that each site is in compliance with applicable regulations (which should reflect the "Criteria for the Classification of Solid Waste Disposal Facilities" promulgated under Section 4004 of RCRA). If a site is not in compliance, the cost of upgrading to compliance status should be estimated.

If the capacities of currently used landfills are not available, they can be estimated using the remaining landfill area (in acres), the average depth of fill (in feet), and the community's annual waste generation rates (in tons per year). The following assumptions are necessary:

- A refuse to cover ratio of 4:1 by volume,
- An in-place density of the refuse of 1,000 pounds per cubic yard, and
- No significant increase in community's waste generation in the future.

The methodology for performing this estimate is shown on Worksheet 2, "Estimation of Remaining Landfill Capacity/Life".

If it is determined that the site has 10 or more years capacity remaining, then for planning purposes, the costs for this site should be used for comparison with the resource recovery option. To do this, the budget for the landfill operation should be obtained. An effort should be made to ensure that it does not include inappropriate items nor omit any hidden costs of the operation. For instance, the landfill operations may be included as part of a larger public works or refuse management budget, including such items as refuse collection and disposal, snow removal and street sweeping. On the other hand, costs for vehicles and other equipment may appear on a separate capital outlay budget and administration costs may be hidden in a general administrative and overhead budget.

If less than ten years landfill capacity remains, costs should be developed for a new landfill which will require the identification of one or more potential sites. If no sites can be located within the borders of the community, then sites in adjoining jurisdictions with sufficient capacity should be identified. In this case, the costs associated with solid waste transportation (either by direct haul or transfer haul) should be investigated and added to the anticipated disposal fee at these sites.

Owing to the site specific nature of landfill costs, no effort has been made to develop generic costs for this guide. The following factors, however, are among the most important in determining the cost of a new landfill:

- Land cost;
- Site preparation;
- Need for leachate controls;
- Equipment requirements;
- Availability of cover material;
- Leachate monitoring requirements; and
- Gas control requirements.

If necessary, community officials should consult other references for detailed procedures for estimating landfill operation costs.

4.5 IDENTIFY AND EVALUATE MARKETS

The successful implementation of a waste-to-energy facility hinges on the availability of a suitable energy market. Indeed, the nature of the resource recovery system implemented should depend on the market(s) that are available for recovered energy. Consequently, perhaps the most critical step in determining the feasibility of resource recovery is the identification and evaluation of potential energy users.

Users of steam and hot water represent the best markets for recovered energy, since the revenues from these products are greater than for electricity. In order to identify and evaluate potential users of these recovered energy products, a market analysis including the following should be conducted:

- Identification of major industries, businesses, and other potential energy users;
- Survey of these potential users to gather information on their energy requirements; and
- Solicitation of letters of interest to purchase recovered energy from those which represent viable markets.

4.5.1 Identify Potential Energy Users

This initial data collection effort is primarily intended to identify all businesses and industries within the marketing area. In many small communities, city or town officials will have a good knowledge of area businesses and industries. This information can often be supplemented with information from directories and business listings. Such listings, while varying from area to area, can generally be obtained with a minimum of effort. Some sources which may be helpful include:

1. List of Industrial Dischargers, EPA Office of Water Enforcement, Feb. 1980.
2. Local Chamber of Commerce.
3. State or regional pollution control authority listings of point sources of air emissions or wastewater discharges.
4. Municipal wastewater treatment works.

The listing of businesses and industries within a community, particularly in the larger ones, will obviously be extensive, containing small businesses which have very small energy requirements. Through an initial screening, many of the included establishments can be eliminated, even without extensive data collection via market surveys. The following questions can be used as an initial screening:

- Is the total energy (steam or hot water) requirement normally very small or highly variable?
- Is there space available for a resource recovery facility within 2 miles of the energy user?

4.5.2 Market Survey

A market survey is the key means of obtaining necessary information to identify qualified potential energy markets. This information will enable a

small community to judge the appropriateness of potential buyers in regard to the important marketing criteria:

- Type of energy used;
- Total energy requirements;
- Daily and seasonal variation in energy demand; and
- Current energy costs.

Market surveys are generally conducted by questionnaire through the mail and followed with a phone call to obtain additional information or verification of data, or to obtain information from businesses which did not respond. A well run survey can be very effective in identifying potential energy buyers and determining their ability to viably incorporate resource recovery into their systems. A typical energy market questionnaire is presented in Appendix B. This information can be used to identify potential energy users and further to compare the compatibility of energy demands with the capabilities of a waste-to-energy system. Obviously, the most desirable energy market would be one which required an amount of energy that is equal to, or greater than, that which can be produced from the available waste stream.

Knowledge of the current and projected costs for energy of a potential market is extremely useful in determining the selling price of steam. The market can be expected to pay only its avoided costs less a discount as an inducement to make a long-term commitment to purchase energy. This avoided cost will depend primarily on the fuel used by the market, but also on the savings that could be realized on the operation, maintenance, and replacement of energy-generating equipment. In turn, these non-fuel related savings will be dependent on whether the market's existing steam plant is operated full-time to supplement purchased steam; is used only for back-up and/or peak operation; or is shut-down completely with the energy-recovery facility providing back-up capability. In addition, an understanding of the market's existing energy situation, and the constraints facing it in the future, will allow the community to take the initiative in setting the price for steam, which could result in the negotiation of a more favorable steam purchase agreement.

In essence then, the market survey should provide the basis for further considering resource recovery. If potential energy buyers exist, i.e. if their location is satisfactory and if their energy demands are compatible with respect to quantity and specifications, then consideration of waste-to-energy systems is warranted.

The investigation of electricity markets may be warranted if no suitable steam customer can be found or if a potential customer has a significant seasonal variation in steam demand, making cogeneration potentially attractive.

The Public Utilities Regulatory Policy Act of 1978 (PURPA) contained provisions to encourage the development of cogeneration and small electric power projects utilizing renewable energy resources, including:

- A requirement that an electric utility purchase electricity from a qualifying facility at fair rates, which were defined as being just and reasonable to the utility, in the public interest, and non-discriminatory to the facility;
- A requirement that an electric utility make such interconnections with a qualifying facility as may be necessary to accomplish purchases or sales of electricity; and
- An exemption for qualifying facilities from state and federal regulations as public utilities.

Regulations issued by the Federal Energy Regulatory Commission (FERC) in February, 1980, required a utility to purchase electricity from resource recovery and other alternative energy facilities at the utility's avoided cost. Utilities were also allowed, but not required, to enter into long-term contracts to purchase this electricity. The administration of this program, including the promulgation of regulations dictating how the avoided cost for individual utilities should be determined, is the responsibility of State Public Utility Commissions (PUCs). In January, 1982, the U.S. Court of Appeals struck down two key provisions of the FERC regulations (American

Electric Power Service Corporation, et al. v. Federal Energy Regulatory Commission, et al.):

- The requirement that the rates paid by a utility for electricity from qualifying facilities be equal to its avoided cost; and
- The blanket right of a qualifying facility to interconnect with a utility, regardless of the substantive and procedural requirements of the Federal Power Act (16 U.S.C. Sec. 824i,k), which require that such interconnections be in the public interest.

At this time, it is uncertain how PURPA will affect the sale of electricity from energy recovery facilities; however, it seems likely that state PUC's will have greater authority in defining the relationship between the utility and the energy recovery facility. Although PUC's in general have not taken an active role in implementing PURPA, electric utilities have entered into serious and fruitful negotiations in several recent projects. In most cases, electric utilities will represent the best market for electricity, since the fair rates determined under PURPA are likely to be equal to, or greater than, the rates they charge large volume industrial, commercial, and institutional users. Where the utility is unwilling or unable to purchase electricity, it may be worthwhile to examine other potential markets, including industries and the municipality itself (particularly its wastewater treatment plant).

In order to evaluate the market for electric power, it will be necessary to collect data on electricity rates and avoided costs from area utilities. Under PURPA, utilities are required to periodically submit data on their avoided costs to state PUC's; thus, this information should be available from these sources, also. In addition, it would be worthwhile to contact the PUC in order to determine its posture towards the sale of electricity from energy recovery facilities and its interpretation of PURPA, and to obtain general information on area utilities which will be useful in assessing them as potential markets for electric power. It will also be necessary to enter into discussions with area utilities in order to determine their interest in purchasing electricity, and the conditions under which they would make these purchases, including price. As for steam, it will be necessary to offer the utility a discount over its avoided cost as an inducement to sign a long-term contract.

The cogeneration of electricity and steam may also represent a viable alternative where the steam demand of a potential market is insufficient to utilize all the MSW generated by the community. It is not possible for this guide to consider all possible cogeneration configurations which could be applied to various site-specific market conditions; however, it does address what is probably the most common application, where the market's steam demand is seasonal, and excess steam during the off-season is used to generate electricity.

This application would involve two turbine generators in parallel -- one back pressure and one condensing. The steam required by the market would be throttled through the back-pressure turbine to produce steam at the desired conditions plus some electricity. The excess steam would be used to drive the condensing turbine generator which would extract as much energy as possible from the steam as electricity and return condensate directly to the boiler. For the purposes of this guide, it is assumed that the market's peak demand will require all the steam produced by the energy recovery facility. Two cogeneration configurations are considered based on the availability of excess steam:

- Configuration I is designed to utilize a maximum of 75 percent of the total steam production in the condensing turbine; and
- Configuration II is designed to utilize a maximum of 50 percent of the total steam production in the condensing turbine.

Worksheet 3 presents the methodology for calculating steam and/or electricity production from MSW.

4.5.3 Letters of Interest

After identification of potential energy users through the market survey, it is desirable to obtain a "Letter of Interest" from prospective users showing their commitment to purchase energy. The incorporation of a resource recovery facility can only be successful with a firm contractual commitment from an energy market. The "Letter of Interest," while not a contractual agreement, represents a firm basis for considering sale of energy to a buyer.

Its objective is to provide more than a general noncommittal statement of willingness; rather, it is intended to actually identify those markets which are truly interested.

The "Letter of Interest" should address the following points:

- Willingness to Participate - the letter should contain a statement from the prospective buyer displaying their interest and willingness to commit to the purchase of material at given conditions.
- Quantity of Energy Needs - the amount of energy that the buyer may be willing to purchase should be specified.
- Energy Characteristics - the buyer should also specify the quality of energy needed. The conditions required for purchase should be included, such as temperature, pressure, and quality of steam where steam is the marketed commodity.
- Energy Price - the buyer should specify what price they are willing to pay for recovered energy.

Without a commitment from prospective energy buyers in the form of "Letters of Interest," community officials should reevaluate their interest in resource recovery since the identification of such interested parties is crucial to the successful implementation of resource recovery.

4.6 PERFORM PRELIMINARY ECONOMIC ANALYSIS

This section is intended to provide a community with a means of quickly and easily developing a resource recovery solid waste management alternative and determining its costs. By using this guide, a community will be able to determine whether or not resource recovery represents a potentially cost-effective disposal alternative for their specific situation. Nevertheless, it should be emphasized that this guide has been developed for a generalized situation, and a site-specific analysis should be performed before the community proceeds with project procurement.

The Preliminary Economic Analysis of resource recovery for the purpose of this study has been divided into six steps:

- System sizing;
- Estimation of capital costs;
- Estimation of annual costs;
- Estimation of revenues;
- Life-cycle costing; and
- Sensitivity analysis.

Following each of these important steps, a community can determine its economic feasibility for resource recovery. Each of these steps are discussed in detail in the following subsections.

4.6.1 System Sizing

Determining the size of the resource recovery system is an important first step in developing system costs. For this stage of evaluation, community officials can effectively determine the size of a system which meets its waste disposal needs. For later stages of system development, specific vendors should be involved in determining individual unit sizes and configurations and a community should undergo more detailed waste stream characterization and generation studies.

For the purpose of this guide, the size of the system will be based on existing waste generation in the planning area and the energy demand of the market.

The following factors need to be considered in determining facility size:

- Quantity of waste available;
- Requirements of the market;
- Desired system redundancy;
- Planned operating schedule; and
- Variations in waste generation.

The most important of these factors is of course the quantity of refuse available for processing. Generally, the system should be designed to accommodate all the processable waste generated by the community, since disposal remains the primary function of a resource recovery system. (As previously mentioned, only 95 percent of the available waste stream will be processable; large bulky items, white goods, etc. will continue to need disposal in a landfill.) In order to ensure that the system can handle all processable waste, excess capacity should be included to account for surges or variation in waste generation during peak periods; however, it is important that the system not be significantly oversized, since this will increase capital costs without generating additional revenues from the sale of energy and tipping fees, thus increasing the net cost per ton of disposal. As a rule of thumb, 10 percent excess capacity should be added to account for waste generation fluctuations. Worksheet 4 presents steps for a community to determine system sizing.

The requirement of the energy market is also an important consideration in determining system size. System capacity should not be greater than that required to meet the demand of the energy market(s). If the market demand for energy is significantly greater than can be produced from the community's refuse, it may be desirable to consider taking waste from neighboring jurisdictions. Conversely, where the energy market has a small energy demand, it may make sense to construct a smaller facility accepting waste from only part of the community.

The requirements of the market will also play a role in determining the redundancy necessary for the system. The best situation is where the market intends to retain its existing energy system to supplement the production of the resource recovery facility and to act as a back-up; thus, no additional redundancy is required beyond that needed to assure refuse disposal. If the market does not want to use the existing system as a back-up, a completely redundant module may be necessary to ensure full production during unscheduled down-time. If the market requires a high degree of reliability, it may be desirable to design even more redundancy into the system by reducing the sharing of other system components such as secondary combustion chambers and

boilers. It should be kept in mind that inclusion of excess redundancy will significantly increase capital costs.

The redundancy designed into the system will also depend on the intended operating schedule of the system. In the situation where the system operates five days per week, routine maintenance can be scheduled on the weekends. However, if the facility operates six or seven days per week, it would be necessary to include an additional unit so that one can always be taken off-line for maintenance. It is usual for modular combustion systems to be operated continuously for 5-6 days, since this reduces wear-and-tear on the furnace refractories resulting from frequent temperature changes, provides efficient utilization of system capacity, and reduces the consumption of auxiliary fuel during start-up.

In many communities, significant seasonal variations in waste generation occur that may dictate the inclusion of excess capacity sufficient to handle peak periods. As previously discussed, 10 percent excess capacity should be added to accommodate such fluctuations.

One factor that need not receive significant consideration at this time is future waste disposal requirements. It is not necessary to size small-scale systems in anticipation of future increases in waste generation, since additional units can be added as increases in waste generation occur. This is one of the major benefits of modular combustion systems, as it eliminates the guess work in predicting future population and waste generation trends, as well as the expense of excess capacity which is not required until several years after start-up.

In developing a generalized methodology for system sizing, it has been necessary to make some assumptions with respect to the factors discussed above:

1. The system will operate continuously for five days per week and be taken off-line for routine maintenance over the weekend.

2. The market will retain adequate back-up capability to handle temporary loss or reduction of energy production due to unscheduled down-time.

3. No extraordinary system redundancy, such as additional combustion chambers or boilers shall be included to increase system reliability.

4. The system shall include 10 percent excess capacity to accommodate peaks in waste generation.

4.6.2 Estimation of Capital Costs

The capital cost of small-scale modular incineration facilities is a function of system capacity. The development of capital costs should, therefore, be based upon the appropriate system size as developed in Section 4.6.1. It is fairly obvious that the selection of a specific vendor could greatly influence the ultimate capital cost of a system; however, from a review of costs obtained from various system vendors, a generalized correlation has been developed between system capacity and capital cost. Cost curves have been developed for systems generating steam, electricity or both energy products (cogeneration), and are presented as part of Worksheet 5. The base capital costs include land, site development, buildings and equipment, and engineering and legal fees. In addition, 10 percent of the base capital cost is included for start-up and shake-down. This estimate does not include financing during construction, which is included in the debt service calculations on Worksheet 6. The capital cost curves were finalized in December, 1981, and should be updated to the current time by using the Chemical Engineering Plant Cost Index (or an equivalent cost index). In addition, they should be escalated further to reflect the impact of inflation on construction costs prior to ground-breaking.

4.6.3 Estimation of Annual Costs

In addition to the initial capital cost of a resource recovery facility, the annual operating costs must be determined. These costs are the expense of keeping the facility running to process MSW and recover marketable commodities. Annual operating costs can be broken down into two individual areas:

- Annualized capital costs; and
- Operating and Maintenance (O&M) costs.

4.6.3.1 Debt Service

Annualized capital costs or the debt service consist of interest payments on borrowed capital and the payback of that capital. These costs must be paid whether the plant operates at full capacity or not. The annualized cost of borrowed capital is dependent upon three factors: the financing approach used, the bond interest rate, and the loan term. The recommended financing strategy for resource recovery projects involves the sale of revenue bonds with or without private equity participation. (Private equity investment can be attracted to a project in return for nominal ownership of the facility and the associated tax advantages, and can considerably reduce overall capital requirements.) Lower financing costs can be achieved through general obligation (G.O.) bonds; however, this approach greatly increases the exposure of the community to the risks associated with the project. This guide considers three financing approaches: revenue bonds, revenue bonds with 25 percent equity participation, and G.O. bonds. The bond interest rate will depend on the type of bond (revenue or G.O.), the credit rating of the issuing municipality or agency, and, in some cases, the credit rating of the other project participants (system vendor and energy market). The interest rate used for this analysis should reflect the current rate obtainable for similar local bond issues. The loan term is based on the expected useful life of the facility, usually considered to be 20 years, and the term of the energy purchase agreement, whichever is shorter.

Where specific information on these factors is not available, the following assumptions should be made for the purposes of a preliminary assessment of feasibility:

- Revenue bond financing;
- Interest rate of 13 percent for revenue bonds or 11 percent for G.O. bonds; and
- Fifteen-year loan term.

Worksheet 6 presents the methodology for determining the annualized capital cost, including a table of multipliers which when applied to the estimate of capital costs will yield the annual debt service.

4.6.3.2 Operating and Maintenance (O&M) Costs

Annual operating and maintenance (O&M) costs are those costs which are necessary to keep a facility operating. These costs include the following items:

- Labor - dependent upon local wage rates, number of personnel required and type of facility;
- Maintenance - materials and labor used for repairs and routine maintenance;
- Auxiliary materials and energy usage - includes supportive electricity, auxiliary fuel, rolling stock, and water needed to operate facility and peripheral equipment;
- Residue disposal - a function of volume reduction and available disposal alternatives;
- Maintenance reserve fund - to cover major maintenance needs, such as the replacement of refractories or boiler tubes; and
- Insurance.

Worksheet 7 contains necessary guidelines for estimating each of these items contributing to the total O&M costs.

4.6.4 Estimation of Revenues

The amount of energy revenues produced by a resource recovery facility, and thus energy revenues, is a function of the quantity (and characteristics) of the solid waste processed and the thermal efficiency of the system. The price received for the energy sold is usually based on the market's existing energy production costs, including a 10 to 25 percent discount as an incentive for a long-term contract. Typically, price increases are indexed in some way to that of the fuel displaced by the recovered energy.

The methodology for estimating energy revenues is contained in Worksheet 8. As energy costs vary considerably according to geography, fuel type and technology, it will be necessary to conduct a detailed interview with the proposed energy market in order to ascertain its current energy costs if information was not forthcoming during the market survey step (Section 4.5.2).

4.6.5 Life-Cycle Costing

It is common practice in the evaluation of public works projects to assess their economics on the basis of the first year of operation; however, the first year of operation of a resource recovery project is not indicative of its potential economic performance in the future. In fact, it should represent the worst possible case over the life of the project. This is due to the combined effect of inflation and the expected escalation of the value of the energy produced by the facility. Over the life of the project, inflation will reduce the real value of the debt service payments. Meanwhile, the revenues from the sale of energy from the facility can be expected to grow at a faster rate than inflation. Operating costs should increase at approximately the same rate as inflation, thus remaining unchanged in real value. The result is that, with time, there should be a reduction in the real net annual operating costs for the facility.

Consequently, any evaluation of the feasibility of resource recovery should involve the assessment of facility economics over the planned life of the facility. This guide presents a simplified life-cycle costing methodology relying on the cash flow analysis (rather than the more complicated techniques using present worth analysis) which can be easily applied and is readily interpreted by public officials. This methodology involves projecting costs and revenues over the 15 or 20 year planning period based on assumptions on inflation and the rate of escalation of energy revenues. The net cost per ton is expressed in current dollars to facilitate interpretation, since inflation renders actual dollar quantities in future years meaningless to most readers. Although predicting the rates for inflation and energy cost escalation is speculative exercise, an attempt has been made in the following section to offer guidelines for selecting values for use in the life-cycle costing analysis.

4.6.5.1 Inflation and Escalation

One measure of inflation is the U.S. Department of Labor's Consumer Price Index (CPI) for Urban Wage Earners and Clerical Workers. The percent annual change (from December to December) is shown in Table 4-1 for the 10 years 1971

TABLE 4-1

Percent Annual Change in Consumer Price Index (CPI)

Year	Percent
1971	3.4
1972	3.4
1973	8.8
1974	12.2
1975	7.0
1976	4.8
1977	6.8
1978	9.0
1979	13.4
1980	12.4

to 1980. The average annual increase over this period was 8.1 percent; however, since the Arab Oil Embargo (1973-74), the rate of increase has been 9.3 percent. Given this history and the present Administration's commitment to controlling inflation, a rate of 9% should be the maximum used in this analysis. Most analysts consider it unlikely that inflation can be held below 5 percent for any extended period; therefore, as a conservative estimate it is recommended that a rate of 7 percent be used in this analysis.

For the purposes of this analysis, it will be assumed that operating and maintenance costs (including labor, parts, utilities, fuel, and residue disposal) will increase with inflation. In the past decade, the costs of municipal services, measured by the Municipal Cost Index published by American City and County, has increased slightly faster than inflation (as measured by the CPI); however, the difference is less than 1 percent and should be ignored for the purposes of this analysis, although it can be examined in the Sensitivity Analysis (see Section 4.6.6) if desired.

The escalation rate for energy revenues is more difficult to predict and will depend on how the contract with the energy purchaser is structured. It is usual for such contacts to contain a pricing mechanism which pegs the price of recovered energy to a conventional fuel, usually the one that is being displaced. Naturally, the increase in revenues will be greater when this displaced fuel is oil rather than coal. Since the Arab Oil Embargo (1973-74), the average annual escalation value of petroleum products has been over 15 percent in real dollars. Although this rate is unlikely to be maintained over the long-term, a rate of 8 percent seems reasonable. To be conservative, a suggested real value escalation rate for revenues where oil is the displaced fuel is 5 percent.

The lifting of Federal controls on natural gas prices is expected to boost the price of this fuel as it finds its market value. Since natural gas is a very desirable fuel, it is likely that its price will rise nearly as fast as that of petroleum fuels; therefore, the suggested real value annual escalation rate for energy revenues where natural gas is displaced is 4 percent.

Coal is a less desirable fuel (since its utilization involves greater use of air pollution control devices and requires the handling of residual materials), which is reflected in its value relative to other fuels; however, as the costs for oil and gas increase, the demand for coal is likely to increase and put some upward pressure on its real value. A safe guess is that the real value of coal will increase in the range of 1 to 4 percent of value over the long-term; therefore, it is suggested that a real value escalation rate of 2 percent be used for energy revenues where coal is the fuel displaced.

The escalation rate for revenues from the sale of electricity is site-specific and depends on the circumstances of the local utility, particularly with respect to such factors as the fuels used to generate the power it produces and purchases, and its need for additional capacity over the planning period. It is recommended that local utility projections of annual cost escalation be used wherever possible. Otherwise, an estimate based on recent electric power price increases is suggested. In most cases, the real value annual escalation rate for electricity should be in the 0-2 percent range.

The escalation rate used for energy revenues should be the sum of the inflation rate and the real value escalation rate assumed for the analysis.

4.6.5.2 Net Annual Costs - Initial Year

The initial year (Year 0) of operation of a resource recovery facility is a minimum of 3 years away from the beginning of planning. This guide will assume a more realistic, but still optimistic, schedule which calls for start of construction (ground breaking) in 2 years and completion of construction, start-up, and shake-down in 4 years. It is necessary to assume a schedule since cost escalation will increase the capital costs prior to construction and energy revenues prior to full operations.

The methodology for calculating the net annual costs for the initial year of operation (Year 0) is contained in Worksheet 9.

4.6.5.3 Life-Cycle Costs - Resource Recovery Alternative

The life-cycle costing analysis adopted for this guide involves the projection of costs and revenues for 5-year intervals over the planned life of the resource recovery facility. In order to avoid the complication of adding modules to the system to accommodate future increases in waste quantity, waste generation is assumed to be constant throughout the planning period. This should not have a significant impact on the validity of the analysis, since the unit cost for resource recovery (net cost per ton) should not alter greatly with the addition of capacity and increased waste throughput.

In order to facilitate comparison with the landfill alternative, this analysis views the resource recovery alternative as a comprehensive solid waste management system by including the costs for landfill disposal of unprocessable waste.

The procedure for the calculation of life-cycle costs for a resource recovery alternative is found in Worksheet 10.

4.6.5.4 Life-Cycle Costs - Landfill Alternative

In order to properly evaluate the resource recovery alternative, it is necessary to determine the life-cycle costs for landfill over the planning period. An accurate estimate of future landfill costs for the community is of critical importance in this step, in order to provide a realistic comparison with the resource recovery alternative; therefore, it is important that the estimate developed pursuant to Section 4.4 reflects the impact of the RCRA Criteria and current/future land costs if a new site is required. Provided that these factors have been taken into account, landfill costs can be assumed, conservatively, to escalate at the rate of inflation. These costs should be entered on Worksheet 11.

4.6.5.5 Life-Cycle Cost Comparison

The best way to compare the life-cycle costs for the resource recovery and landfill alternatives is graphically. Worksheet 12 contains a blank sheet for this purpose. In most cases, the early years of a resource recovery

alternative will be more expensive than landfill; however, in most cases, the resource recovery alternative will become cheaper than landfilling before the end of the planning period. If this occurs before the mid-point of the planning period, then resource recovery can be considered to have definite potential as a cost-effective solid waste management alternative. If this occurs after the mid-point, then resource recovery may not be a cost-effective alternative; however, this may be due to the generally conservative assumptions made for this analysis. It is recommended that these assumptions be reviewed and their effect on project economics be assessed in the Sensitivity Analysis discussed in the following section before a decision is made to proceed with or stop project development.

4.6.6 Sensitivity Analysis

In developing the economic analysis of the previous section, it was necessary to make a number of assumptions based on predictions of the future behavior of the economy. As the future undoubtedly has some surprises in store for us, it is necessary to assess the impact that any deviations from these predictions will have on the economics of a resource recovery project. It is particularly useful to consider "worst case" scenarios in order to focus attention on the inherent risks of resource recovery. "Best case" scenarios are valuable in that they highlight the need to structure the project so that potential savings/profits are shared equitably, although they should not be used to raise expectations unreasonably.

The following factors are prime candidates for consideration in sensitivity analysis for resource recovery:

- Debt service;
- Energy revenues;
- Inflation rate;
- O&M cost escalation rate; and
- Waste quantity.

The debt service payment could be affected by the financing approach used, the interest rate obtainable at the time the bonds are issued, and a greater than anticipated initial capital investment due to cost overruns and the requirement for significant modifications during start-up and shake-down.

The future revenues from the sale of energy could be greater or lower than anticipated due to a number of occurrences. The cost of the energy market's displaced fuel could escalate at a higher or lower rate than expected. The high cost of the displaced fuel could prompt the market to convert to a cheaper energy source. The energy market could go out of business or close the plant using the recovered energy. Poor system reliability could result in less MSW being processed and less energy being produced and sold. Protection against some of these negative occurrences is available through contractual means, but others represent risks which the community will not be able to avoid.

The principal effect of inflation on the economics of a resource recovery project is on the relative value of the debt service compared with other operating costs and revenues. A low inflation rate will result in the debt service over the life of the project being higher (in real terms) than anticipated.

The O&M cost for the facility could increase at a faster rate than inflation and/or could be higher than anticipated, due to repeated equipment failures.

A lower than anticipated quantity of waste delivered to the facility could also have a significant impact on project economics, since revenue would be significantly reduced without corresponding reductions in debt service and, to a lesser degree, O&M costs.

The sensitivity analysis should examine those factors which are of particular concern to the community considering resource recovery. It is useful to examine each factor separately so that its impact on project economics can be judged. "Worst case" and "best case" scenarios can also be developed where several factors are adjusted at a time. Worksheet 13 contains

several copies of a life-cycle cost summary sheet for calculating project economics for each scenario examined.

4.7 MAKE PROCEED/STOP DECISION

The decision to proceed with the development of an energy recovery project, identified through the use of this guide, should be based on two factors:

- the technical and economic feasibility of the proposed project; and
- the level of commitment on the part of all project participants to the implementation of energy recovery.

Technical feasibility, provided this guide has been followed carefully, can be assumed at this point. It will be necessary to retain an engineering consultant to review the proposed project to identify any technical problems. If significant problems are discovered, the feasibility of the project should be reassessed at that time.

In order for an energy recovery project to be considered economically feasible, it should be the cheapest solid waste disposal alternative over the length of the planning period. Typically, the cost for such a project is higher during the early years of operation and may exceed the cost for landfill; however, resource recovery can still be considered to be feasible if it appears to be the cheapest alternative for the major part of the planning period. Recently, financing approaches have been developed to alleviate the problem of high early-year disposal costs.

Even if the proposed project is feasible according to the analysis performed using this guide, the implementation process is long and sometimes difficult. Without the firm commitment to do what is necessary to ensure implementation from all the participants, particularly the sponsoring political jurisidiction(s) and the proposed energy market, the project can easily become stalled and eventually abandoned. The Phase II and III planning steps (see Chapter 5.0) require a considerable investment of time and money on

the part of these participants to achieve success. It is important that an able and diligent project manager be hired to lead the planning effort on behalf of the community, and that the appropriate engineering, management, financial, and legal consultants be retained. The acquisition of this staff and consulting expertise can represent a considerable expense for a small community; however, if the community is not prepared to commit the necessary resources to the project, it should not proceed with implementation.

In addition to the community sponsoring the project, it is essential that the proposed purchaser of recovered energy show more than just token interest in this effort. The active participation and cooperation of the purchaser in many aspects of project development, including the determination of facility configuration, siting, and negotiation of the energy purchase contract, can greatly facilitate implementation.

Other factors must also be examined in making this decision, and, in particular, potential sources of opposition to the project should be identified and assessed. Private firms involved in solid waste collection and disposal may see the proposed project as a threat to their livelihood. The community must be prepared to take the necessary steps to ensure that a sufficient quantity of waste is delivered to the planned facility where some or all of this waste is currently controlled by private firms. Also, public opposition to the site or other features of the project can easily prevent implementation. The existence and severity of such problems should be determined before the decision to proceed or stop is made, so that the potential for opposition, and its impact on the implementation process, can be assessed.

In summary, the decision to proceed with or to stop the development of an energy recovery project should be made in the light of both the merits of the project and the political realities of the community. The decisionmaker must answer the following questions:

- Is the project the best and most cost-effective solid waste management alternative for the community?
- Can the project be implemented?

5.0 PLANNING FOR RESOURCE RECOVERY PROCUREMENT ... THE NEXT STEPS

A major barrier to the widespread implementation of resource recovery across the nation has been the complex nature of the planning process. This process is a unique blend of technical, marketing, financial, legal, and organizational steps which must be integrated into a coherent and coordinated implementation program. It is essential to include a large number of participants, each having a different perspective on resource recovery and vested interest in the outcome of the planning effort. These participants typically include:

- Local government(s);
- Purchasers of recovered energy (and/or materials);
- System and equipment vendors;
- Investment banking firms;
- Private collection and disposal firms;
- Engineering and management consultants; and
- The general public.

Although each of the participants will be familiar with certain aspects of resource recovery planning, few will, at the outset, comprehend the entire process. Consequently, it is critical that the process allows for the continuing education of these participants regarding the issues and complexities of project implementation in order to facilitate the orderly resolution of problems and conflicts.

The value of a carefully structured planning program with well defined decision points and milestones should not be underestimated. By indicating the sequences of events leading to implementation, one can prevent the project participants from becoming overwhelmed by the complexities of the planning process. In addition, it can provide a measure of progress as steps towards project implementation are completed. Such a program can convince project participants that the implementation effort is genuine and will succeed in leading to the construction of a facility. The resulting confidence can create momentum towards project completion.

The resource recovery model planning program for small communities is summarized in Figure 5-1 which shows a generalized flow diagram for the steps that must be taken to implement a resource recovery project. This model should not be regarded as a rigid "cookbook" procedure for resource recovery planning, but as a flexible guide to structuring a planning program around the unique characteristics of each individual community.

A discussion of the planning model for Phase I (Feasibility Analysis) was presented in Section 3.1 and will not be repeated here. This section will discuss the planning associated with resource recovery project procurement, which is divided into two phases:

- Phase II - Procurement Planning; and
- Phase III - Procurement.

5.1 PHASE II - PROCUREMENT PLANNING

The objective of Phase II is to finalize the project concept (including such critical details as the market, site, and technology), to make decisions on the approaches to procurement and financing, and to strengthen the commitments for purchase of energy and for waste supply from participating jurisdictions. The remainder of this section outlines the steps that must be taken to achieve this objective.

5.1.1 Establish Project Management Structure

A structured planning program is perhaps most important in Phase II where the steps and their outputs are less tangible; thus, it is important to define carefully what steps need to be accomplished and what specific outputs must be generated.

The resources necessary to complete Phase II will be significantly greater than for Phase I. It is desirable to acquire the services of a firm or a team of firms with considerable previous experience in resource recovery project implementation to assist the community in structuring a project which has a high probability of success at as low a cost as possible.

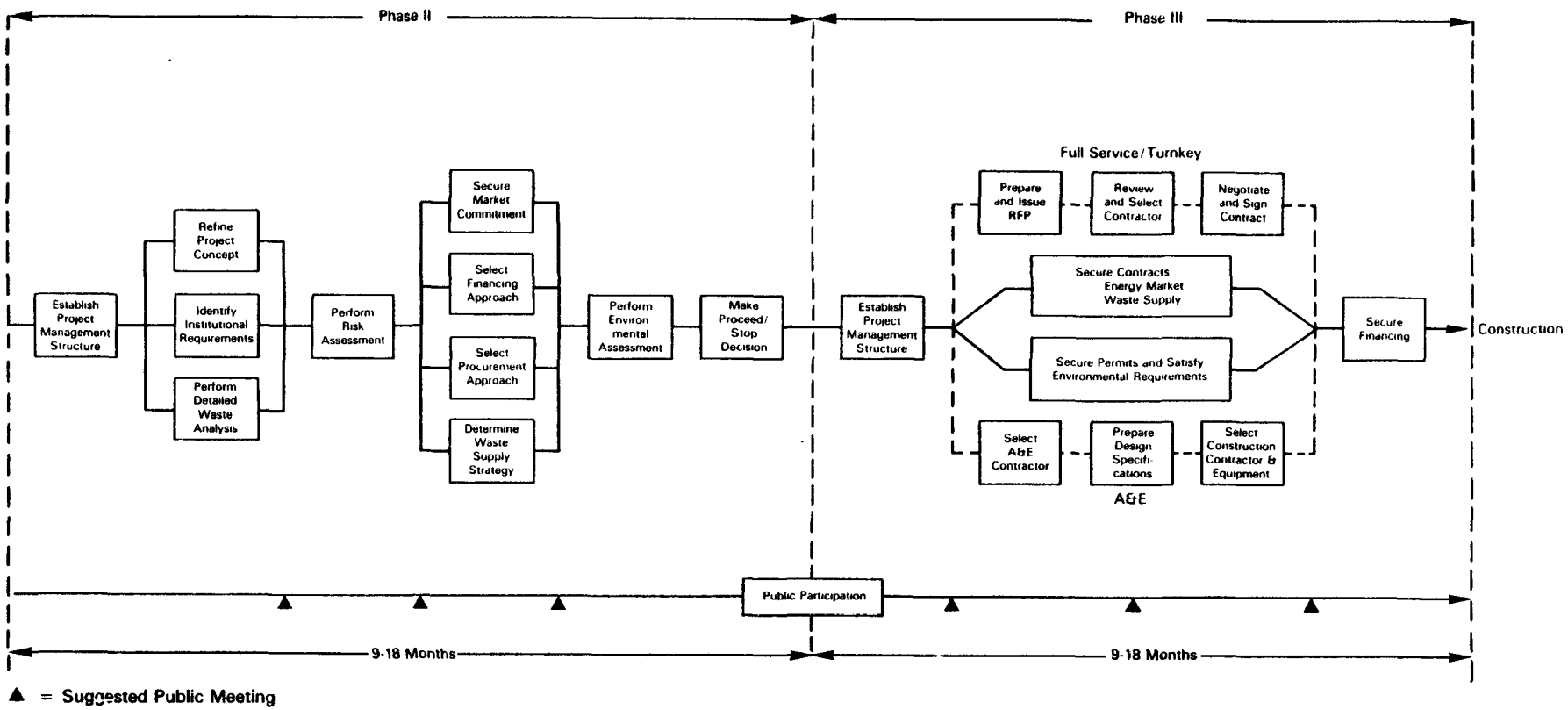


Figure 5-1
Resource Recovery Planning Model for Small Communities
Procurement Planning and Procurement

5.1.2 Refine Project Concept

This step represents a bridge between Phase I and Phase II activities. It should include a review of the Preliminary Economic Analysis performed by the community to confirm its results. If more than one viable resource recovery alternative has been identified, a decision should be made as to which has the best chance of success and should be pursued. The details of the selected alternative should be developed, including site selection, final system configuration, source for utilities (electricity, sewer, water for boiler, make-up and quench), and other design criteria. A revised cost estimated based on these site specific conditions should be prepared.

5.1.3 Identify Institutional Requirements

It may be necessary for the community to develop a new institutional framework to implement, manage, and operate a resource recovery facility. This would not be necessary where the community wishes to finance the project with general obligation (G.O.) bonds and manage the project through its public works department; however, if more than one community is involved in the project and/or revenue bonds are to be used for financing, it may be desirable to create an authority to act as the implementing agency and to manage the project once it is operating. This body may be granted the power to issue bonds and to enter into long-term contracts for the sale of energy and for waste supply. This step should be used to identify alternative institutional frameworks for evaluation in subsequent steps in Phase II.

Also at this juncture, it is appropriate to consider closely how the supply of solid waste for the facility should be secured for the planned life of the project. Again, if only one jurisdiction is involved and both collection and disposal is publicly controlled, waste control should not be a problem; however, if the proposed project involves several jurisdictions and/or the private sector is extensively involved in either collection or disposal, then action is required. Participating jurisdictions may need to enact ordinances to gain control of the waste stream and enter into long-term "put-or-pay" contracts with facility owners. A careful assessment of alternative methods for achieving waste should be identified by project planners during this step.

5.1.4 Perform Detailed Waste Analysis

A more accurate and/or updated evaluation of the waste that would supply the proposed facility is an important Phase II activity. This need not involve a costly weighing and sampling program at local landfills. It is becoming increasingly acceptable to estimate quantities of residential and commercial solid waste using population data and assuming a per capita waste generation rate of 1,000-1,200 pounds per year. Further assumptions can be made with respect to characteristics such as energy, moisture, and ash content, using national averages. The industrial component of the waste stream should be quantified and characterized separately through a survey and/or site visits of industrial facilities within the community.

5.1.5 Perform Risk Assessment

A full understanding of the risks associated with implementing and operating a resource recovery facility by all the participants in the project is critical to assure that a meaningful concensus regarding the structure of the project is reached. The term structure refers to the nature of the legal agreements with respect to the sale of energy, delivery of waste, guarantees, procurement, financing, facility operation, and management. Familiarity with these risks will encourage the development of preliminary agreements which are both realistic and fair and can be converted into signed contracts in Phase III with a minimum of difficulty. Risks in resource recovery can be categorized into four general areas:

- Risks Involving Waste Supply. Any changes in the anticipated quantity or composition can have a dramatic effect on the economic viability of the project. If the quantity of waste or its energy content is less than expected, then less energy can be generated, resulting in less revenues from the sale of energy. If the composition changes such that a proportion of the waste is unprocessable and must be landfilled, the project's costs for residue disposal rise. Changes in the waste stream can occur due to changes in consumer behavior, withdrawal of one or more jurisdictions from the project, and competition from a cheaper disposal site.

- Risks Involving Markets. Reduction in the price of competing sources for the energy that the facility sells will depress the revenues for energy sales. In addition, the user of the recovered energy could go out of business or close the plant using the product(s).

- Risks Involving Facility Construction. Delays in facility construction and start-up as well as unanticipated increases in the cost for key items of equipment can result in cost overruns. In addition, the generation of revenues (from energy sales and tipping fees) to cover the debt service would be delayed, increasing financing costs.

- Risks Involving Facility Operation. The technical reliability of the facility is essential to the economic success of the project. Unless system availability targets are met, costs incurred for the disposal of wastes which cannot be processed and the resulting loss of revenues from energy sales could seriously undermine the economic viability of the project.

  Higher operating costs could be caused by inflationary pressures (causing them to increase at a faster rate than energy revenues) or by lower than anticipated labor productivity.

  The health and safety of the project labor force and the facility itself could be jeopardized by the presence of explosives, or radioactive or chemically dangerous chemicals in the incoming wastes. This could result in costly unscheduled down-time and increase the project's insurance costs.

The remainder of Phase II is devoted largely to determining how these risks should be managed. The following steps: Select Financing Approach, Select Procurement Approach, and Determine Waste Supply Strategy; should represent an integrated effort to allocate the risks of the project among the participants in a rational manner. In general, it is a good idea to allocate a risk to that party which is best able to control that risk. However, one cannot expect a risk to be accepted by any party without an economic incentive.

For example, a community may be very concerned that the system it acquires operates properly and meets the desired performance specifications. As the system vendor is in the best position to control this particular risk, the community could decide to procure the system via the 'turnkey' approach whereby the system vendor is responsible if the system does not meet the agreed upon specifications; however, the vendor would demand a higher price to assume this risk (to cover his costs of posting performance bonds and/or for making modifications during shakedown).

5.1.6 Secure Market Commitment

The purpose of this step is to develop a basic understanding with the proposed energy market regarding the terms of the energy purchase agreement. The issues which should be addressed at this stage include:

- Quantity and characteristics of the energy product;
- Delivery schedule;
- Price;
- Formula for price escalation;
- Contract duration;
- Contract termination; and
- Responsibility for providing back-up energy during facility down-time.

In most instances, it would be useful to develop a draft contract at this stage. In all cases, a strong written commitment should be solicited from the proposed market indicating its intent to enter into a contract to purchase the energy produced by the facility.

5.1.7 Select Financing Approach

There are a variety of ways to finance resource recovery facilities which a community should examine carefully to determine their relative merits. The capital intensive nature of resource recovery generally requires the issuance of tax-exempt municipal bonds. A municipality can issue either general obligation (G.O.) bonds, which are backed by its full faith and credit, or revenue bonds, which are secured by the anticipated revenues (tipping fees and energy sales) from the facility. For a community with a very good bond rating, the G.O. bond will give the lowest interest rate. Since, in theory, revenue bonds are not secured by the taxing authority of the municipality, they come under very close scrutiny of the investment banking community to ensure key project elements (particularly contracts) are in place. In practice, however, the investment banking community also requires that one or more of the participants in the project guarantees repayment of the bonds.

Recently, creative financing approaches have been introduced to overcome the unfavorable early-year economics of most resource recovery projects. In the early years, high operating costs can be defrayed by the payment of interest only on the debt or by increasing the initial capital investment to set up an escrow account for this purpose. In later years, due to the increase in energy revenue and inflation, the project will be in a position to support higher debt service payments.

Private equity financing of an entire project is uncommon due to the low return on investment inherent to resource recovery; however, some private equity participation in a project can result in lower financing costs. In return for this direct equity contribution, the system vendor can receive the Federal tax benefits (energy and investment tax credits and tax depreciaiton) for the entire facility, which effectively reduces the size of the debt that must be serviced through revenues. A similar reduction in overall financing costs can be achieved through a leveraged lease arrangement which enables a third party to receive these tax benefits.

5.1.8 Select Procurement Approach

Resource recovery projects can be procured through three basic approaches:

- A&E Approach. The architect and engineer (A&E) approach is the traditional method of procuring public works projects. It normally involves two separate procurements: one for engineering services for facility design, including facility design and equipment selection, preparation of competitive bid specifications, and construction supervision, and a second for construction and equipment installation.

- Turnkey Approach. In this approach, the city contracts with a single contractor for a complete package including facility design, construction, equipment supply, and start-up. The contractor is required to satisfy various acceptance criteria in turning over to the community a fully operating facility. This approach can be modified to have the contractor operate the facility.

- Full-Service Approach. The third option involves total implementation, operation, and possible ownership of the facility by a private firm. In this case, the contractor is retained to provide a service rather than a facility, and his responsibilities include financing, contracts for energy sales and waste delivery, and operation. The contractor may own the facility outright or lease it from the municipality.

The A&E approach is sometimes referred to as a competitive procurement process since the contracts for construction and equipment are awarded to the lowest responsive bidder. In contrast, the turnkey and full-service approaches are negotiated procurements which are perhaps better suited to systems which are difficult to specify in advance; however, these approaches are sometimes restricted by state laws requiring competitive bidding on the terms of price. Although the A&E approach gives the community the greatest control over the nature and quality of the facility implemented, it also requires that it bear the greatest share of the risks, including many of those associated with system performance. Consequently, the trend in resource recovery procurement in recent years has been towards negotiated procurements, mainly because a considerable share of the risk can be transferred to the contractor -- particularly those which he is in the best position to control.

5.1.9 Develop Waste Supply Strategy

Under this step, a strategy to ensure the delivery of sufficient solid waste to the facility must be developed. In many cases, waste flow control is not an issue, particularly where the existing collection and disposal system is operated by the community; however, if there is significant private sector involvement in collection and/or if alternative disposal sites are available within reasonable hauling distance, obtaining control of the waste can be critical for project success.

Although a community may have the authority to pass an ordinance requiring disposal of waste at a designated facility, such an ordinance is difficult to enforce effectively. In order to successfully control the waste, it is necessary that the resource recovery facility is economically attractive to private haulers. One means of achieving this is to charge all solid waste generators a "user's fee" for the facility through a direct tax levy and eliminate the tipping fee at the facility. A second approach is to subsidize the tipping fee at the facility out of general tax revenues.

5.1.10 Perform Environmental Assessment

If an environmental impact assessment of the project is required, it should be performed during Phase II. Even if it is not required, it may be

advisable to generate some information regarding environmental issues, such as air pollution and impacts on local traffic, that will be of concern to the public. In addition, requirements for environmental permits should be identified at this time.

5.1.11 Proceed/Stop Decision

Based on a review and update of the feasibility study, the outcome of the preliminary discussions with project participants on the structure of the proposed project, and the environmental assessment, a decision whether to proceed with the project should be made.

5.2 PHASE III - PROCUREMENT

Phase III represents the final steps that must be taken before a project can proceed to construction. It includes the selection of the system vendor or the A&E and construction contractors, execution of all contracts, securing of all necessary permits, and the raising of the capital necessary to finance the project.

The steps necessary to accomplish Phase III will vary depending on the procurement approach chosen, as indicated in the planning model (see Figure 5-1). The selection procedure for the contractor or contractors to design and construct the facility in the competitive (A&E) procurement approach differs from that of the negotiated approaches (turnkey/full-service). The steps involving the finalization of contracts, securing permits, and project financing are similar for all procurement approaches.

5.2.1 Project Management

At the outset of Phase III, it is necessary to identify the steps that are necessary to achieve procurement and to set a schedule for their completion. Also, the resources necessary to perform these steps should be identified and acquired. In addition to the community's in-house management needs, the following consulting or financial services may be required:

- Bond counsel;
- Investment banking firm;

- Management/engineering consulting firm; and
- Legal counsel.

The bond counsel and investment banking firms will be required in order to prepare the financing plan for the project and in issuing and marketing bonds. Management and/or engineering consultants can provide valuable assistance in reviewing proposals and negotiating contracts with system vendors and energy purchasers. Outside legal counsel may be necessary to review contracts and to provide advice on other legal issues (e.g., waste flow control ordinances).

5.2.2 Turnkey/Full-Service Approaches

The steps comprising the procurement of a resource recovery system by the turnkey and full-service approaches are essentially the same, differing only in the nature of the contract that is executed between the implementing agency and the system vendor.

5.2.2.1 Prepare and Issue RFP

A detailed request for proposals (RFP) must be prepared and issued to interested and/or qualified system vendors. (In order to limit the number of proposals that must be evaluated, these firms may be pre-screened by soliciting qualifications statements and eliminating those firms which are determined to be unqualified to provide the desired system.) The RFP should contain as much information as possible about the proposed project in order to ensure that the proposals are responsive to the community's requirements. In particular, the RFP should specify the requirements pertaining to technical performance, management, economics and financing, contractual considerations, and environmental and aesthetic considerations.

5.2.2.2 Review and Select Contractor

The community should assemble a review committee composed of public officials and interested citizens (i.e., city/county engineer, public works director, treasurer, counsel, etc.) with the necessary skills to evaluate the proposals submitted by system vendors. In most cases, it is advisable to

retain technical consultants to assist the committee in evaluating the proposals.

The outcome of this step should be the selection of one or perhaps two system vendors with whom the community will engage in contract negotiations in the following step.

5.2.2.3 Negotiate and Sign Contracts

In this step, a contract with a system vendor to provide a system is negotiated and signed. A recent trend in resource recovery system procurement has been competitive negotiation whereby the community enters into simultaneous contract negotiations with the system vendors that submit the two most responsive proposals. In this way, the vendors are under pressure to negotiate contract terms which are most beneficial to the community in order to win the contract; however, this approach can be more time consuming than negotiations with a single proposer and could delay project implementation.

5.2.3 A&E Approach

The A&E approach involves the selection of an architect and engineering firm to design the facility, prepare bid specifications, and oversee the construction by a separate contractor selected through a competitive procedure.

5.2.3.1 Select A&E Contractor

In this step, qualifications statements are solicited from A&E consulting firms familiar with resource recovery, in general, and small-scale systems, in particular. Following review and evaluation of these statements, a firm is selected.

5.2.3.2 Prepare Design and Bid Specifications

The A&E contractor prepares a preliminary design for the facility and develops bid specifications for the buildings, equipment, and other components of the designed facility.

5.2.3.3 Select Construction Contractor

The selection of the construction contractor and major equipment components is generally conducted according to established procurement procedures (in many cases mandated by law). Usually, following advertisement, Invitation to Bid (IFB) packages containing the specifications for the desired facility, should be sent to interested firms. The resulting bids are evaluated on the basis of cost and technical merits, and the lowest responsive bidder is generally selected. On the basis of that bid, a contract is prepared and signed.

5.2.4 Secure Contracts

In this step, final negotiations for contracts for energy sales and waste supply should be concluded and the contracts signed. Agreements as to the basic conditions for these contracts should have been reached in Phase II and substantial further negotiations should not be necessary; however, it is advisable to allow a generous amount of time, since difficulties over contractual language could delay execution of the contract, and, thus, the project.

5.2.5 Secure Permits and Satisfy Environmental Regulations

In this step, the necessary pre-construction permits identified in Phase II should be applied for and acquired. These may include permits for air emissions, National Pollution Discharge Elimination System (NPDES), construction, operation, and highway access.

5.2.6 Secure Financing

The capital necessary to finance construction of the facility should be raised according to the financing approach selected in Phase II. This step includes the following:

- Preparation of a detailed financing plan by the investment banking firm;
- Preparation of a bond resolution by bond counsel;

- Approval of the bond issues by public officials and by referendum, if necessary; and
- Marketing of the bonds.

Once this step has been completed, facility construction can begin.

APPENDIX A

WORKSHEETS

WORKSHEET 1

Preliminary Estimation of Community Waste Generation

Waste generation can be estimated using a variety of techniques. If an estimate of community waste generation in tons per year (TPY) is available from refuse weighing data, landfill records, or another reliable method, enter figure on Line 2. If such sources of data do not exist, the following methodology will provide an estimate of waste generation, based on a national per capita waste generation rate.

1. Enter population of community (include all of the area to be served by the disposal facility) _____ Persons

2. Multiply Line 1 by 0.5 tons/capita/year to obtain waste generation in TPY _____ TPY

WORKSHEET 2

Estimation of Remaining Landfill Capacity/Life

The determination of remaining life of the currently used landfill is an important screening consideration in evaluating resource recovery feasibility. If there is suitable land disposal capacity available, then resource recovery is probably not a viable alternative.

The estimation of remaining landfill capacity and subsequently the number of years that the landfill can be used is dependent upon the available volume of unused landfill and the current annual waste generation rate. The following steps provide the methodology for determining the remaining life of landfill.

1.	Enter unfilled area in acres remaining at existing landfill site	_____	acres
2.	Enter average depth of fill in feet	_____	feet
3.	Multiply Line 1 by Line 2 to obtain remaining landfill volume	_____	acre-feet
4.	Multiply Line 3 by 646* tons per acre-foot to obtain remaining capacity of landfill	_____	tons
5.	Divide Line 4 by annual waste generation in TPY (Worksheet 1, Line 2) to obtain remaining life of landfill	_____	years

*Based on in-place density of refuse of 0.5 ton/cu. yd., refuse to cover value ratio of 4:1 and conversion factor of 1615 cu. yd./acre-foot, i.e. (0.5 ton/cu. yd. x 1615 cu. yd./acre-foot x 4/5).

WORKSHEET 3

Estimation of Energy Production (Continued)

The flexibility of Configuration I is achieved at the cost of efficiency, the turbines have a larger total capacity, yet will be driven by the same quantity of steam, and turbine efficiency decreases with throughput. Worksheet Figure 3-1 is provided for the determination of electricity generation for each cogeneration configuration depending on the quantity of excess steam available. Worksheet Table 3-1 is included to facilitate the calculation of electricity and steam production for cogeneration.

A. Steam Production

1.	Enter annual waste generation in TPY (Worksheet 1, Line 2)	_____ TPY
2.	Calculate annual processable waste quantity as 95 percent of Line 1	_____ TPY
3.	Determine daily processable waste quantity by dividing Line 2 by 250 days per year (assuming 5 operating days per week, 10 holidays per year)	_____ TPD
4.	Enter appropriate steam rate (thousand pounds per ton of MSW): -- 5.1 thousand lbs/ton for process steam (150 psi saturated) -- 4.7 thousand lbs/ton for electricity generation or cogeneration (600 psi, 600°F)	_____ thousand lbs/ton
5.	Multiply Line 3 by Line 4 to obtain daily marketable steam production	_____ thousand lbs/day
6.	Multiply Line 5 by 250 to obtain annual steam production. Enter here and, if steam production only is being considered, on Line 24 also.	_____ thousand lbs/yr.

B. Electricity Generation

7.	Multiply Line 6 by 65.0 KWH/thousand lbs. to obtain maximum annual electricity generation	_____ KWH/year

WORKSHEET 3

Estimation of Energy Production

The amount of energy that can be produced from MSW is important in comparing the compatibility of the energy demand of a potential market and the waste quantities available in the area. This Worksheet provides a methodology for calculating both steam and electricity production from a given quantity of municipal solid waste (MSW). If steam production is being considered, then Section A of this worksheet should be completed. If electricity generation or cogeneration is to be considered then Sections B and C, respectively, should also be completed.

To calculate energy production, it is necessary to make assumptions regarding the heating value of the refuse (4,500 BTU/lb.), thermal efficiency of the boiler (60%), and condensate return conditions (75% at 200°F). The conditions of the output steam were assumed to be 150 psi saturated for heating or process applications and 600 psi superheated (600°F) for electricity generation or cogeneration. For electricity generation, the use of a single condensing turbine generator was assumed. Although a variety of turbine types and configurations could be used in cogeneration depending on site-specific considerations, it was assumed that the most common application would be where steam is the primary energy output and excess steam would be used to generate electricity. This would require a configuration involving back-pressure turbine and condensing turbine generators in parallel. The steam supplied to the market would be throttled to process/heating conditions (150 psi, saturated) via the back-pressure turbine, resulting in the generation of more electricity. Excess steam would be used to drive the condensing turbine generator, which would extract as much energy as possible from the steam in the form of electricity, and return condensate directly to the boiler. Two configurations are considered depending on the availability of excess steam:

- Configuration I - would accomodate a maximum of 75% of the total steam production in the condensing turbine generator.
- Configuration II - would accomodate a maximum of 50% of the total steam production in the condensing turbine generator.

WORKSHEET 3

Estimation of Energy Production (Continued)

8. Calculate average annual electricity generation as 95% of Line 7 to allow for turbine down-time. Enter here and on Line 25. _____ KWH/year

9. To obtain daily electricity production, divide Line 8 by 250 days per year. _____ KWH/day

10. To obtain system capacity, divide Line 9 by 24 hours per day. _____ KW

C. Cogeneration

11. Enter average daily steam production from Line 5 for every month under Column A on Worksheet Table 3-1.

12. Enter the proposed market's average daily steam demand for each month under Column B.

13. For each month, enter in Column C the average daily steam sold (A or B, whichever is lower).

14. Calculate average daily excess steam available (A minus C) for each month and enter in Column D.

15. Calculate percent excess steam (D/A x 100) and enter under Column E.

16. Select system configuration (50% or 75% maximum excess steam) based on Column E. If excess steam is significantly greater than 50% in more than one month, use configuration to accomodate a maximum 75% excess steam. Otherwise use 50% excess steam configuration. _____ %

17. Using Worksheet Figure 3-1, determine the electricity generation rate (KWH/thousand lbs. steam) for each month, based on excess steam availability (Column E) and system configuration (50% or 75% maximum excess steam). Enter in Column F.

WORKSHEET 3

Estimation of Energy Production (Continued)

18. To calculate average daily electricity generation, multiply average daily steam production (Column A) by the electricity generation rate (Column F) for each month and enter in Column G.

19. To calculate average monthly electricity generation, multiply average daily electricity generation (Column G) by average operating days per month (Column H) for each month and enter in Column I.

20. Total Column I to obtain annual electricity generation (KWH/year). _____ KWH/year

21. Calculate marketable electricity production as 95% of Line 20 to allow for turbine down-time. Enter on Line 25.

22. Calculate monthly marketable steam production for each month by multiplying average daily steam sold (Column C) by the average operating days per month (Column H). Enter in Column J.

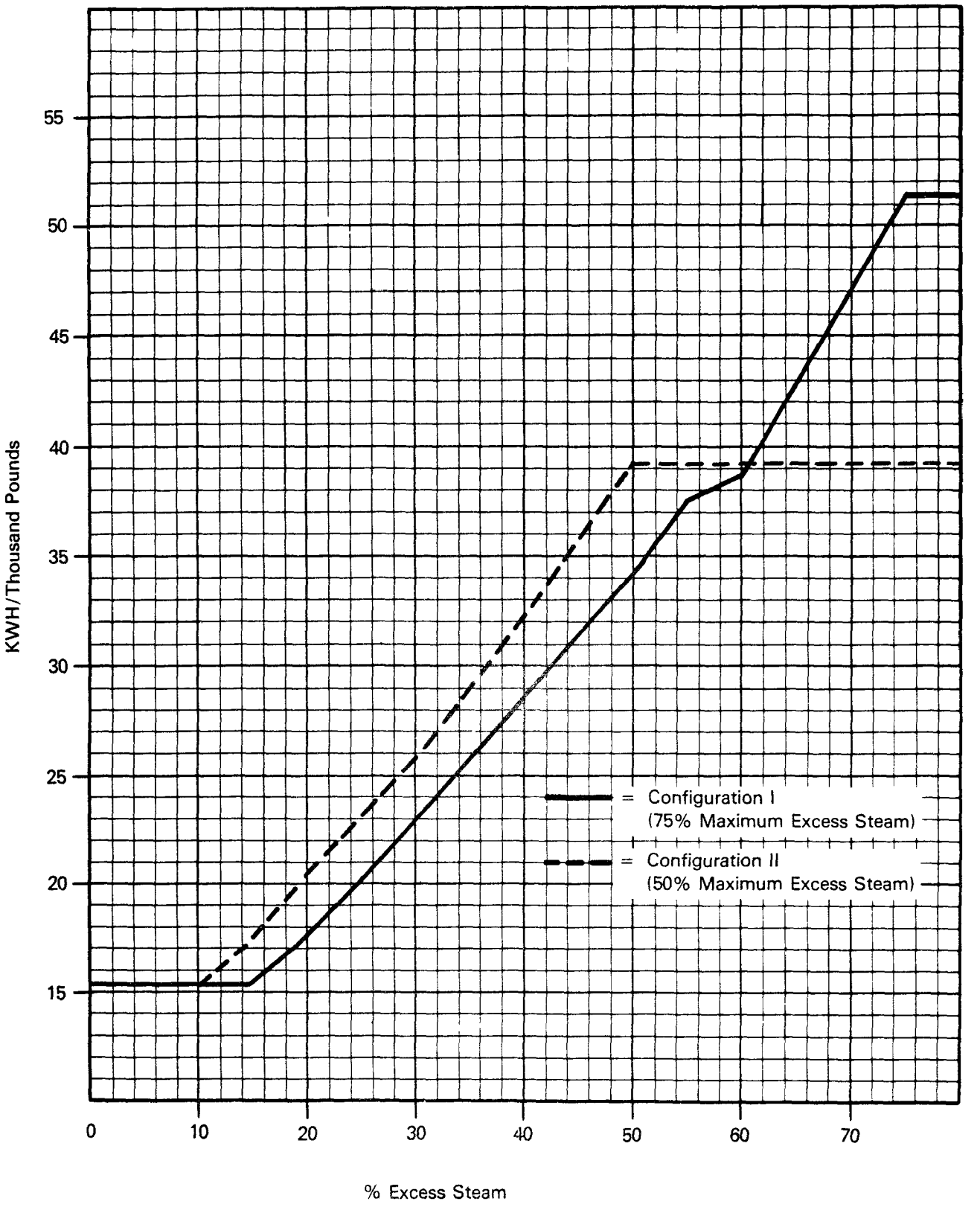
23. Total Column J to obtain annual steam production. Enter on Line 24.

D. Summary of Energy Production

24. Annual marketable steam production. _____ thousand lbs/year

25. Annual electricity generation. _____ KWH/year

Worksheet Figure 3-1
Electricity Generation from Cogeneration Systems



WORKSHEET TABLE 3-1: Cogeneration Energy Production

	A	B	C	D	E	F	G	H	I	J
	Avg. Daily Steam Prod. (Thous. lbs/day)	Avg. Daily Steam Demand (Thous. lbs/day)	Avg. Daily Steam Sold (Thous. lbs/day)	Avg. Daily Excess Steam (Thous. lbs/day)	% Excess Steam	Electricity Generation Rate (KWH/thous. lbs.)	Avg. Daily Elec. Gen. (KWH/day)	Avg. Operating Days/Mo. (days/mo.)	Avg. Monthly Elec. Gen. (KWH/mo.)	Avg. Monthly Marketable Steam Prod. (Thous. lbs/mo.)
JAN								21		
FEB								19		
MAR								21		
APR								21		
MAY								21		
JUN								21		
JUL								21		
AUG								21		
SEP								21		
OCT								21		
NOV								21		
DEC								21		
							ANNUAL TOTAL	250		

WORKSHEET 4

Calculation of System Size

In the previous worksheet, a methodology was presented to compute the quantity of steam that can be produced by the resource recovery system. Whereas this figure is important to identifying a compatible energy market, the system size is important to designing and costing the facility. Of course the type and quantity of steam that must be produced is important to facility design, but for the purposes of this feasibility analysis, the system size will determine subsequent economics. The following methodology incorporates a 10 percent increase in the previously determined daily processable waste quantity of Worksheet 3. This increase provides an assurance of adequate capacity for variations in waste generation without excessively oversizing the system resulting in large excess costs.

1. Enter daily processable waste quantity (Worksheet 3, Line 3) in TPD _____ TPD

2. Multiply Line 1 by 110% (to assure adequate capacity to accomodate peak waste generation) to obtain system size for subsequent calculations _____ TPD

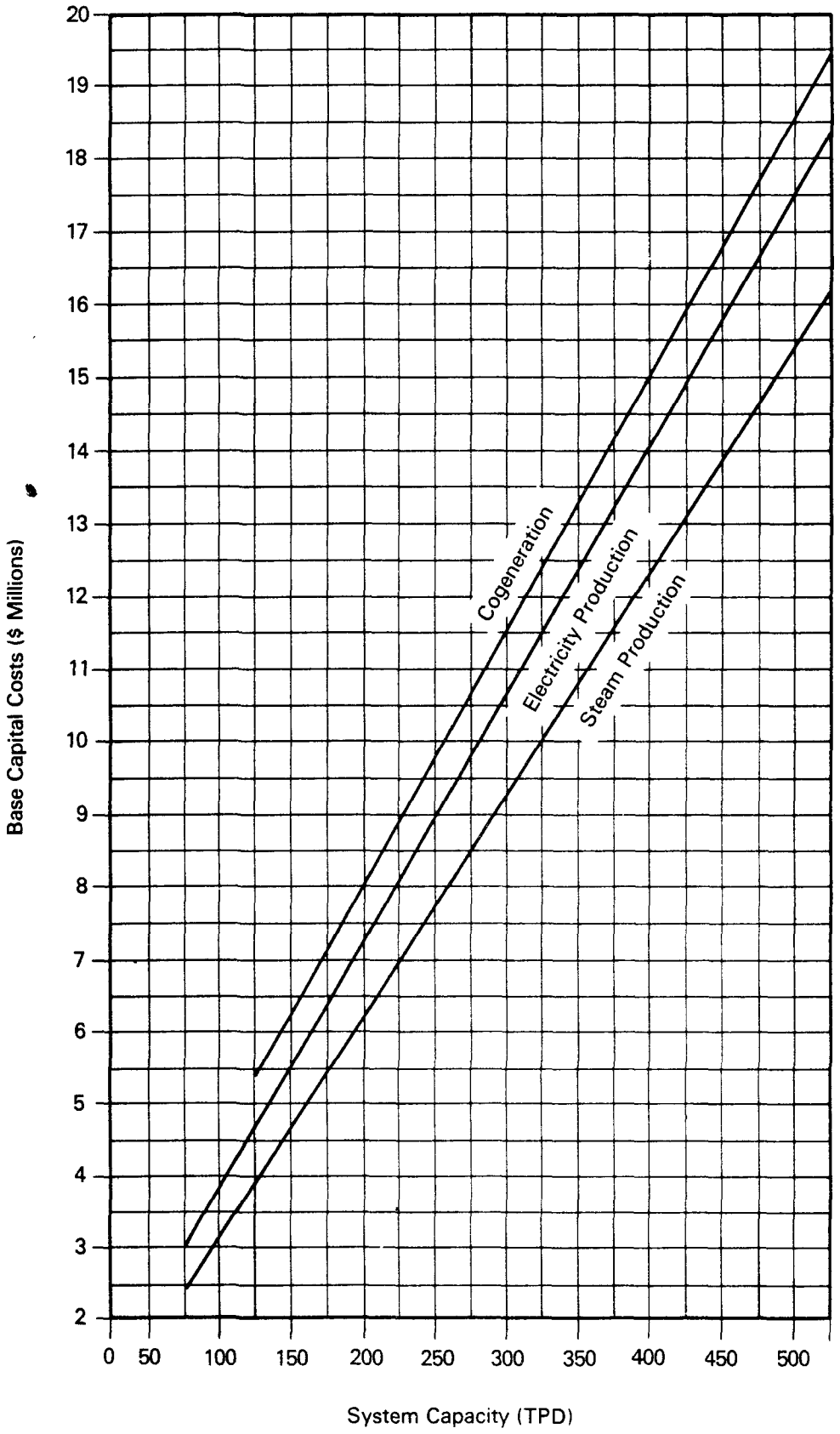
WORKSHEET 5

Estimation of Capital Costs

This Worksheet provides the means to estimate the base capital costs for a system given its capacity (TPD) and the energy products produced: steam, electricity or both. The curves shown in Worksheet Figure 5-1 represent generic base capital costs for modular combustion systems and include land, site development, buildings and equipment, and all engineering and legal fees. These costs were finalized in December, 1981, when the Chemical Engineering Plant Cost Index was 305.3 (preliminary). This index, or equivalent, should be used to update capital costs to current time.

1.	Enter system size (Worksheet 4, Line 2).	_____ TPD
2.	Using the system size, find the estimated base capital costs from Worksheet Figure 5-1 using the appropriate curve (steam production, electricity production, or cogeneration).	$ _____
3.	Calculate start-up and shake-down cost as 10% of Line 2.	$ _____
4.	Obtain capital costs by adding Lines 2 and 3.	$ _____
5.	Update Line 4 to current year by multiplying by X/305.3, where X = current CE Plant Cost Index published by Chemical Engineering.	$ _____
6.	Escalate costs to ground-breaking by multiplying Line 5 by $(1 + i)^2$ where i = rate of inflation.	$ _____

Worksheet Figure 5-1
Base Capital Costs



WORKSHEET 6

Estimation of Debt Service

The annual costs of a facility consist of two components: the debt service or annualized capital cost and the annual operating and maintenance (O&M) costs. The first of these is the payback of borrowed capital and any associated interest, and is a function of the financing approach, the bond interest rate and the loan term. Three financing approaches are considered by this guide: revenue bonds, revenue bonds with 25% equity participation, and general obligation (G.O.) bonds. If the appropriate financing approach cannot be determined, revenue bond financing should be assumed. The interest rate assumed for this analysis should reflect the current rate for the type of bonds to be issued and the credit rating of the issuing municipality or agency. If unknown, rates of 11% and 13% should be assumed for G.O. and revenue bonds, respectively. The loan term should be equal to the planned life of the project or the term of the energy purchase agreement, whichever is less. If unknown, a loan term of fifteen years should be assumed.

The debt service multipliers shown in Worksheet Table 6-1 enable debt service to be calculated from the capital cost estimate developed in Worksheet 5. These multipliers include financing during construction, underwriter's fees (1.5% and 3.5% of total bond issue for G.O. and revenue bonds, respectively), and, for revenue bonds, debt service reserve (one year's debt service) less the income from the investment of this reserve, assuming a return on this investment equal to the bond interest rate.

1. Enter escalated base capital cost (Worksheet 5, Line 6) $_____

2. Enter bond interest rate and loan term. _____%
   _____yrs.

3. Using the bond interest rate and loan term, obtain the annual payment multiplier for the selected financing approach from Worksheet Table 6-1 _____

4. Multiply Line 3 by Line 1 to obtain the debt service $_____

WORKSHEET TABLE 6-1

Debt Service Multipliers

Bond Interest Rate (%)	Revenue Bonds		Revenue Bonds w/25% Equity Participation		G.O. Bonds	
	15 Years*	20 Years*	15 Years*	20 Years*	15 Years*	20 Years*
5.0	.1353	.1052	.1015	.0789	.1215	.0973
5.5	.1413	.1108	.1060	.0831	.1267	.1024
6.0	.1476	.1165	.1107	.0874	.1322	.1076
6.5	.1532	.1225	.1149	.0919	.1378	.1130
7.0	.1607	.1288	.1205	.0967	.1434	.1186
7.5	.1677	.1353	.1257	.1015	.1494	.1244
8.0	.1748	.1422	.1311	.1066	.1554	.1304
8.5	.1824	.1493	.1368	.1120	.1618	.1366
9.0	.1905	.1566	.1429	.1174	.1684	.1429
9.5	.1986	.1643	.1489	.1232	.1750	.1496
10.0	.2074	.1727	.1556	.1295	.1821	.1567
10.5	.2163	.1811	.1622	.1358	.1892	.1637
11.0	.2260	.1900	.1695	.1425	.1968	.1712
11.5	.2358	.1993	.1769	.1495	.2044	.1787
12.0	.2462	.2092	.1847	.1569	.2123	.1867
12.5	.2574	.2194	.1931	.1645	.2207	.1948
13.0	.2687	.2304	.2019	.1728	.2290	.2034
13.5	.2811	.2418	.2108	.1813	.2378	.2121
14.0	.2938	.2536	.2203	.1902	.2469	.2211
14.5	.3073	.2664	.2305	.1998	.2563	.2305
15.0	.3216	.2797	.2412	.2098	.2659	.2402
15.5	.3369	.2937	.2527	.2203	.2761	.2501
16.0	.3531	.2088	.2648	.2316	.2865	.2605
16.5	.3701	.3247	.2776	.2435	.2972	.2712
17.0	.3881	.3415	.2911	.2561	.3082	.2822
17.5	.4077	.3593	.3058	.2694	.3197	.2936
18.0	.4285	.3786	.3214	.2839	.3316	.3055

*Loan term

WORKSHEET 7

Calculation of Annual Operating and Maintenance Costs

Operating and maintenance (O&M) costs, the day-to-day costs necessary to keep the facility operating, are a component of the annual cost of a facility. The many individual contributing costs to the total O&M cost are included in the following worksheet.

1. Enter quantity of processable waste (Worksheet 3, Line 2) _____ TPY

Calculate each of the following cost components:

2. Labor

   2a. Enter labor costs from Worksheet Figure 7-1 $_____

   2b. Overtime (10 percent of Line 2a) = $_____

   2c. Benefits (30 percent of Line 2a) = $_____

   2d. Add Lines 2a, 2b, and 2c to obtain annual labor costs $_____

   2e. Escalate Line 2d to current year by multiplying by X/281.5, where X = current Consumer Price Index for All Urban Consumers (CPI-U) $_____

3. Maintenance - Calculate as 1.2% of base capital costs (Worksheet 5, Line 5) $_____

4. Electricity*

   4a. Multiply 30 KWH/ton by Line 1 to obtain total annual electricity usage _____ KWH

   4b. Multiply Line 4a by local electricity rate ($/KWH) to obtain annual electricity costs. (If local electricity rates are not available, use general rate of $0.06/KWH) $_____

---

*Omit if planned facility will generate electricity.

WORKSHEET 7

Calculation of Annual Operating and Maintenance Costs (Continued)

5. Auxiliary Fuel**

5a. Multiply Line 1 by 2.2 gal/ton (for No. 2 fuel oil) or 0.3 thousand cu. ft. (for natural gas, if available) to obtain annual auxiliary fuel usage _____ gal. or thousand cu. ft.

5b. Multiply 5a by local cost for No. 2 fuel oil ($/gal.) or natural gas ($/thousand cu. ft.) to obtain annual auxiliary fuel costs $_____

6. Rolling Stock

6a. Multiply 0.3 gallon #2 diesel/ton by Line 1 to obtain yearly gallons _____ gallons

6b. Multiply Item 6a by local diesel costs ($/gal) to obtain annual rolling stock costs $_____

7. Water

7a. Multiply 0.2 thousand gal/ton by Line 1 to obtain the total annual water consumption _____ thousand gal

7b. Multiply Line 7a by local water costs ($/thousand gal) to obtain annual water costs. (If local water costs are not available, use general rate of $0.30/thousand gal.) $_____

8. Residue Disposal

8a. Multiply Line 1 by 0.4 to obtain annual quantity of residue _____ TPY

8b. Multiply line 8a by estimated residue disposal cost per ton to obtain annual residue disposal cost*** $_____

** Some modular incinerator systems do not require auxiliary fuel.

***The cost of residue disposal, including transportation, will vary considerably according to local circumstances. Although this material is easily landfilled, state regulations may require disposal in a secure landfill which would increase costs considerably. If the community intends to operate its own disposal site for residue, use disposal cost of $5/ton (or $12/ton for secure disposal).

WORKSHEET 7

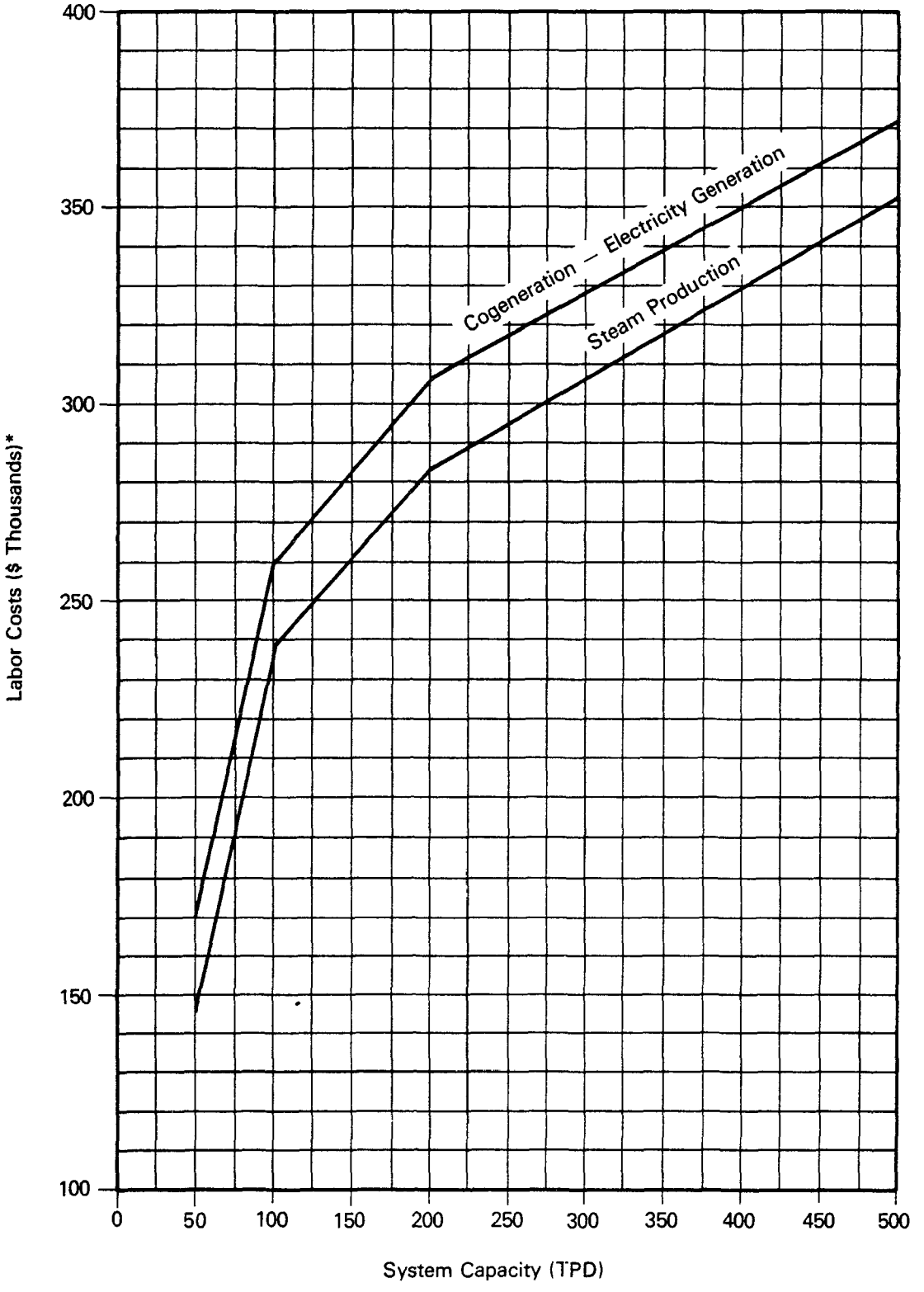
Calculation of Annual Operating and Maintenance Costs (Continued)

9. Insurance (1% of base capital cost - Worksheet 5, Line 5) $_____

10. Maintenance reserve (1% of base capital cost - Worksheet 5, Line 5) $_____

11. Total annual O&M Costs (Add Lines 2e, 3, 4b, 5b, 6b, 7b, 8b, 9, and 10) = $_____

Worksheet Figure 7-1
Labor Cost Estimate



*Cost estimates based on labor requirements and rates shown in Table 7-1.

WORKSHEET TABLE 7-1

Labor Requirements and Rates

Personnel Title	Plant Capacity (TPD) 50	100	200	300	400	500	Salaries/ Labor Rates**	Hours/Year
Plant Manager	1	1	1	1	1	1	$25-35,000 yr.	--
Shift Foreman	-	2	3	3	3	3	$12/hr.	2000
Process Operator	4	6	6	6	6	6	$10/hr.	2000
Maintenance Mechanic	1	1	2	3	4	5	$10/hr.	2000
Electrician*	(1)	(1)	(1)	(1)	(1)	(1)	$10/hr.	2000
Scale Clerk	1	1	1	1	1	1	$6/hr.	2000
TOTAL	7	11	13	14	15	16		

*For electricity generation and cogeneration only.

**Salaries and labor rates were largely dependent on geographical location, and can be expected to vary by as much as ± 20%. These costs were finalized in December, 1981, when the Consumer Price Index for All Urban Consumers (CPI-U) was 281.5.

WORKSHEET 8

Estimation of Revenues for Energy Sales

The revenues from sale of recovered steam and/or electricity must reflect the price that energy buyers are willing to pay. This information, generally obtained through the market survey (Appendix B), will be based upon the market's existing energy production or purchase costs. Since the resource recovery system will be displacing a fairly steady energy source, a price discount is often included as an incentive for a long-term contract. Revenues from sale of energy can be calculated as follows:

1.	If steam will be sold, enter annual marketable steam production from Worksheet 3, Line 24	_____ thousand lbs/yr.
2.	Enter price for steam which market is willing to pay*	$_____/thousand lbs
3.	Multiply Line 1 by Line 2 to obtain annual steam revenues	$_____
4.	If electricity will be sold, enter annual electricity generation from Worksheet 3, Line 25	_____ KWH/yr
5.	Calculate in-house usage by multiplying annual quantity of processable waste (Worksheet 3, Line 2) by 30 KWH/ton	_____ KWH/yr
6.	Subtract Line 5 from Line 4 to obtain net annual electricity production	_____ KWH/yr
7.	Enter price for electricity sold	$_____/KWH
8.	Multiply Line 6 by Line 7 to obtain annual electricity revenues	$_____
9.	Add Lines 3 and 8 to obtain total annual revenues	$_____

*If not known, estimate price based on market's avoided fuel costs minus a 15% discount as an incentive to enter into a long-term contract.

WORKSHEET 9

Net Annual Costs - Initial Year (Year 0)

Any economic evaluation of resource recovery feasibility should involve the assessment of cost over the entire planned life of the facility. A first-year economic analysis will not accurately reflect the economic performance of a facility in comparison to other disposal alternatives. The worksheets that follow provide a methodology for performing a life-cycle cost analysis based upon a cash-flow analysis. Each of these worksheets provides the means for calculating key steps of the life-cycle cost analysis.

This worksheet supplies the steps necessary to update the facility costs estimated in previous worksheets to the initial year of operation. This is essential since the actual first year of facility operation is a minimum of 3 years from the initial planning phase. For the purposes of this methodology, it is recommended that the start of construction be assumed at 2 years and operation at 4 years from the time of this feasibility analysis.

1.	Enter debt service (Worksheet 6, Line 4)	$_____
2.	Enter annual O&M costs (Worksheet 7, Line 11)	$_____
3.	Escalate O&M costs to Year 0 by multiplying Line 2 by $(1 + i)^4$, where i = the inflation rate	$_____
4.	Calculate gross annual operating costs in Year 0 by adding Lines 1 and 3	$_____
5.	If steam will be sold, enter revenues from sale of steam (Worksheet 8, Line 3)	$_____
6.	Escalate steam revenues to Year 0 by multiplying Line 5 by $(1 + e)^4$, where e = escalation rate for steam revenues (where unknown, use escalation rate for displaced fuel)	$_____
7.	If electricity will be sold, enter revenues from sale of electricity (Worksheet 8, Line 8)	$_____
8.	Escalate electricity revenues to Year 0 by multiplying Line 7 by $(1 + e)^4$, where e = escalation rate for electricity	$_____

WORKSHEET 9

Net Annual Costs - Initial Year (Year 0) (Continued)

9.	Calculate total revenues in Year 0 by adding Lines 6 and 8	$_____
10.	Calculate net operating costs by subtracting Line 9 from Line 4	$_____
11.	Enter total processable waste quantity in TPY (Worksheet 3, Line 2)	_____ TPY
12.	Obtain net cost per ton in Year 0 by dividing Line 10 by Line 11	$_____/ton

WORKSHEET 10

Life-Cycle Costs - Resource Recovery Alternative

The life-cycle costing for the resource recovery alternative presented in this worksheet projects costs and revenues in constant dollars for 5-year intervals through the planned life of the resource recovery facility. Worksheet Table 10-1 is a tabulation sheet to be used in conjunction with this worksheet in developing the net cost per ton for each 5-year interval.

1. On Worksheet Table 10-1, enter the following cost items from Worksheet 9 on the lines under Year 0:

   - Debt service (Enter Line 1 from Worksheet 9 on Line a)
   - Annual O&M costs (Enter Line 3 from Worksheet 9 on Line b)
   - Steam revenues (Enter Line 6 from Worksheet 9 on Line e if steam will be sold)
   - Electricity revenues (Enter Line 8 from Worksheet 9 on Line f if electricity will be sold)

2. Calculate quantity of unprocessable waste by multiplying total waste quantity (Worksheet 1, Line 2) by 5%. _____ TPY

3. Calculate cost for landfill disposal of unprocessable waste by multiplying Line 2 by disposal cost per ton, using an estimate for disposal cost ($ per ton) developed according to guidelines presented in Section 4.4. $_____

4. Update the cost for unprocessable waste disposal to Year 0 by multiplying by $(1 + i)^4$, where i = rate of inflation. Enter on Line c under Year 0.

5. Calculate gross annual costs for the resource recovery alternative by adding Lines a, b, and c. Enter on Line d under Year 0.

6. Calculate total revenues by adding Lines e and f and entering the total on Line g under Year 0.

7. Calculate net annual costs by subtracting Line g from Line d. Enter on Line h under Year 0.

WORKSHEET 10

Life-Cycle Costs - Resource Recovery Alternative (Continued)

8. Enter inflation rate (see Section 4.6.5.1) _____%

9. Enter escalation rate(s) for energy revenues (see Section 4.6.5.1) _____% (steam) _____% (electricity)

10. Enter debt service from Year 0, Line a, under each interval (Year 5, Year 10, ... etc.)

11. Calculate the O&M for each 5-year interval (Year 5, Year 10, ... etc.) by multiplying Year 0, Line b, by $(1+i)^n$, where i = inflation rate (Line 8) and n = interval year. (For example: for i = 7%, multiply Line a by $(1 + .07)^5$ for Year 5.) Enter on Line b for each 5-year interval.

12. Calculate landfill cost for each 5-year interval by multiplying Year 0, Line c, by $(1 + i)^n$, where i = inflation rate (Line 8) and n = interval year. Enter on Line c for each 5-year interval.

13. If steam will be sold, calculate steam revenues at each 5-year interval by multiplying Year 0, Line e, by $(1 + e)^n$ where e = escalation rate (Line 9) and n = interval year. (Example: for e = 5%, multiply Line e by $(1 + .05)^{10}$ for Year 10.) Enter on Line e for each 5-year interval.

14. If electricity will be sold, calculate electricity revenues at each 5-year interval by multiplying Year 0, Line f, by $(1 + e)^n$ where e = escalation rate for electricity (Line 9) and n = interval year. Enter on Line f for each 5-year interval.

15. For each 5-year interval, calculate the gross annual costs by adding Lines a, b, and c. Enter on Line d.

16. Calculate toal revenues for each 5-year interval by adding Lines e and f and enter totals on Line g.

17. For each 5-year interval, calculate net annual costs by subtracting Line g from Line d. Enter on Line h.

WORKSHEET 10

Life-Cycle Costs - Resource Recovery Alternative (Continued)

18. Enter total waste quantity in TPY (Worksheet 1, Line 2) on Line i under Year 0 and each 5-year interval.

19. For Year 0 and each 5-year interval, calculate net cost per ton by dividing Line h by Line i. Enter on Line j.

20. Calculate net cost per ton in current dollars by multiplying Line j under each interval year by $(1 + i)^{-n}$, where i = inflation rate and n = interval year + 4 (i.e. number of years from current time to interval year under consideration). Enter on Line k.

Life-Cycle Costs - Resource Recovery Alternative

	Year 0	Year 5	Year 10	Year 15	Year 20
a. Debt Service	------	------	------	------	------
b. Annual O&M Costs	------	------	------	------	------
c. Landfill Cost (unprocessable waste)	------	------	------	------	------
d. Gross Annual Costs (Profit)	------	------	------	------	------
e. Steam Revenues	------	------	------	------	------
f. Electricity Revenues	------	------	------	------	------
g. Total Revenues	------	------	------	------	------
h. Net Annual Costs	------	------	------	------	------
i. Total Annual Waste Quantity (TPY)	------	------	------	------	------
j. Net Cost (Profit) Per Ton (Actual $)	------	------	------	------	------
k. Net Cost (Profit) Per Ton (Current $)	------	------	------	------	------

WORKSHEET 11

Life-Cycle Costs - Landfill Alternative

The life-cycle cost of landfilling is important to provide a comparison with the economics of resource recovery. In general, the cost of a properly run landfill can expect to increase with inflation, resulting in a constant cost in real value. This of course assumes that upgrading the landfill to meet newly instituted RCRA regulations is not necessary. Such factors should be included in developing costs of landfill, but are beyond the scope of the estimation and therefore not included.

1. Enter current landfill cost estimates ($/ton), developed according to guidelines presented in Section 4.4, for year 0 and for each 5-year interval and enter results below:

Year 0	Year 5	Year 10	Year 15	Year 20
------	------	------	------	------

WORKSHEET 12

Life-Cycle Cost Comparison

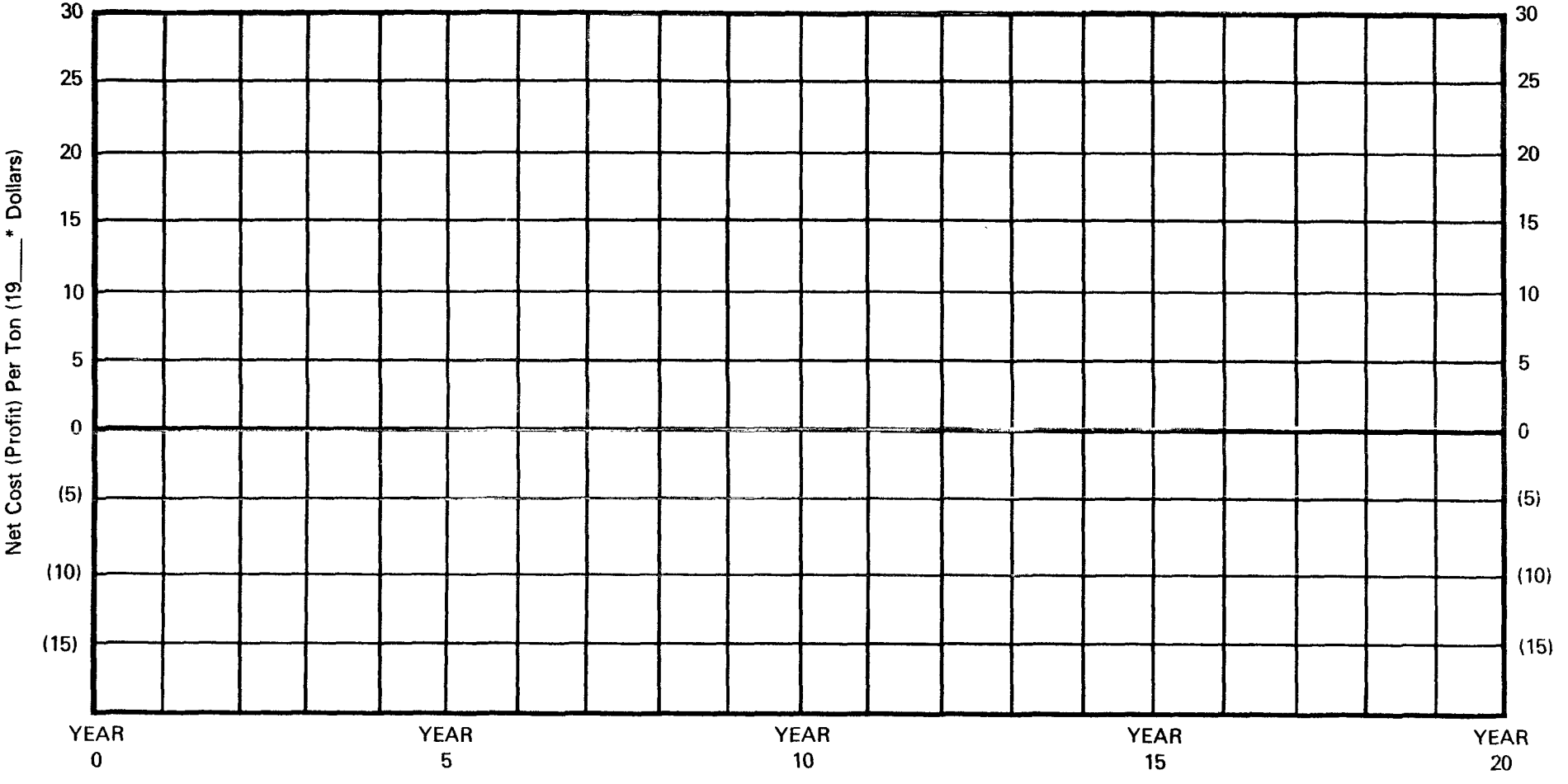
For the sake of comparison of landfill costs with the proposed resource recovery option, this worksheet and accompanying Worksheet Figure 12-1 provide a graphic comparison of the costs developed in Worksheets 10 and 11. It essentially provides the means for graphing costs throughout the planning period for easy comparison.

1. Enter net cost per ton in current dollars for Year 0 and each 5-year interval of the resource recovery alternative (from Worksheet 10, Table 10-1, Line k) on the attached graph, Figure 12-1. Draw cost curve.

2. Likewise, enter net cost per ton in current dollars for the landfill alternative from Worksheet 11. Draw cost curve.

3. Note where these curves intersect, i.e., before or after the mid-point of the planning period.

Worksheet Figure 12-1
Life Cycle Cost Comparison



*Enter Current Year

WORKSHEET 13

Sensitivity Analysis

The preceding economic analysis was based on a number of assumptions and it is advisable to assess the impact of any deviations from these assumptions on project feasibility. This can be done by repeating the appropriate calculations in the preceding Worksheets using different assumptions and recalculating the life-cycle costs using the summary tables provided (Worksheet Tables 13-1 through 13-5). Comparison of these sensitivities with the base case developed in Worksheet 10 can be facilitated by plotting the results of each sensitivity calculation on Worksheet Figure 13-1.

WORKSHEET TABLE 13-1

Analysis of Sensitivity to: _____

	Year 0	Year 5	Year 10	Year 15	Year 20
a. Debt Service	------	------	------	------	------
b. Annual O&M Costs	------	------	------	------	------
c. Landfill Cost (unprocessable waste)	------	------	------	------	------
d. Gross Annual Costs (Profit)	------	------	------	------	------
e. Steam Revenues	------	------	------	------	------
f. Electricity Revenues	------	------	------	------	------
g. Total Revenues	------	------	------	------	------
h. Net Annual Costs	------	------	------	------	------
i. Total Annual Waste Quantity (TPY)	------	------	------	------	------
j. Net Cost (Profit) Per Ton (Actual $)	------	------	------	------	------
k. Net Cost (Profit) Per Ton (Current $)	------	------	------	------	------

WORKSHEET TABLE 13-2

Analysis of Sensitivity to: _____

	Year 0	Year 5	Year 10	Year 15	Year 20
a. Debt Service	------	------	------	------	------
b. Annual O&M Costs	------	------	------	------	------
c. Landfill Cost (unprocessable waste)	------	------	------	------	------
d. Gross Annual Costs (Profit)	------	------	------	------	------
e. Steam Revenues	------	------	------	------	------
f. Electricity Revenues	------	------	------	------	------
g. Total Revenues	------	------	------	------	------
h. Net Annual Costs	------	------	------	------	------
i. Total Annual Waste Quantity (TPY)	------	------	------	------	------
j. Net Cost (Profit) Per Ton (Actual $)	------	------	------	------	------
k. Net Cost (Profit) Per Ton (Current $)	------	------	------	------	------

WORKSHEET TABLE 13-3

Analysis of Sensitivity to: _____

	Year 0	Year 5	Year 10	Year 15	Year 20
a. Debt Service	------	------	------	------	------
b. Annual O&M Costs	------	------	------	------	------
c. Landfill Cost (unprocessable waste)	------	------	------	------	------
d. Gross Annual Costs (Profit)	------	------	------	------	------
e. Steam Revenues	------	------	------	------	------
f. Electricity Revenues	------	------	------	------	------
g. Total Revenues	------	------	------	------	------
h. Net Annual Costs	------	------	------	------	------
i. Total Annual Waste Quantity (TPY)	------	------	------	------	------
j. Net Cost (Profit) Per Ton (Actual $)	------	------	------	------	------
k. Net Cost (Profit) Per Ton (Current $)	------	------	------	------	------

Analysis of Sensitivity to: _____

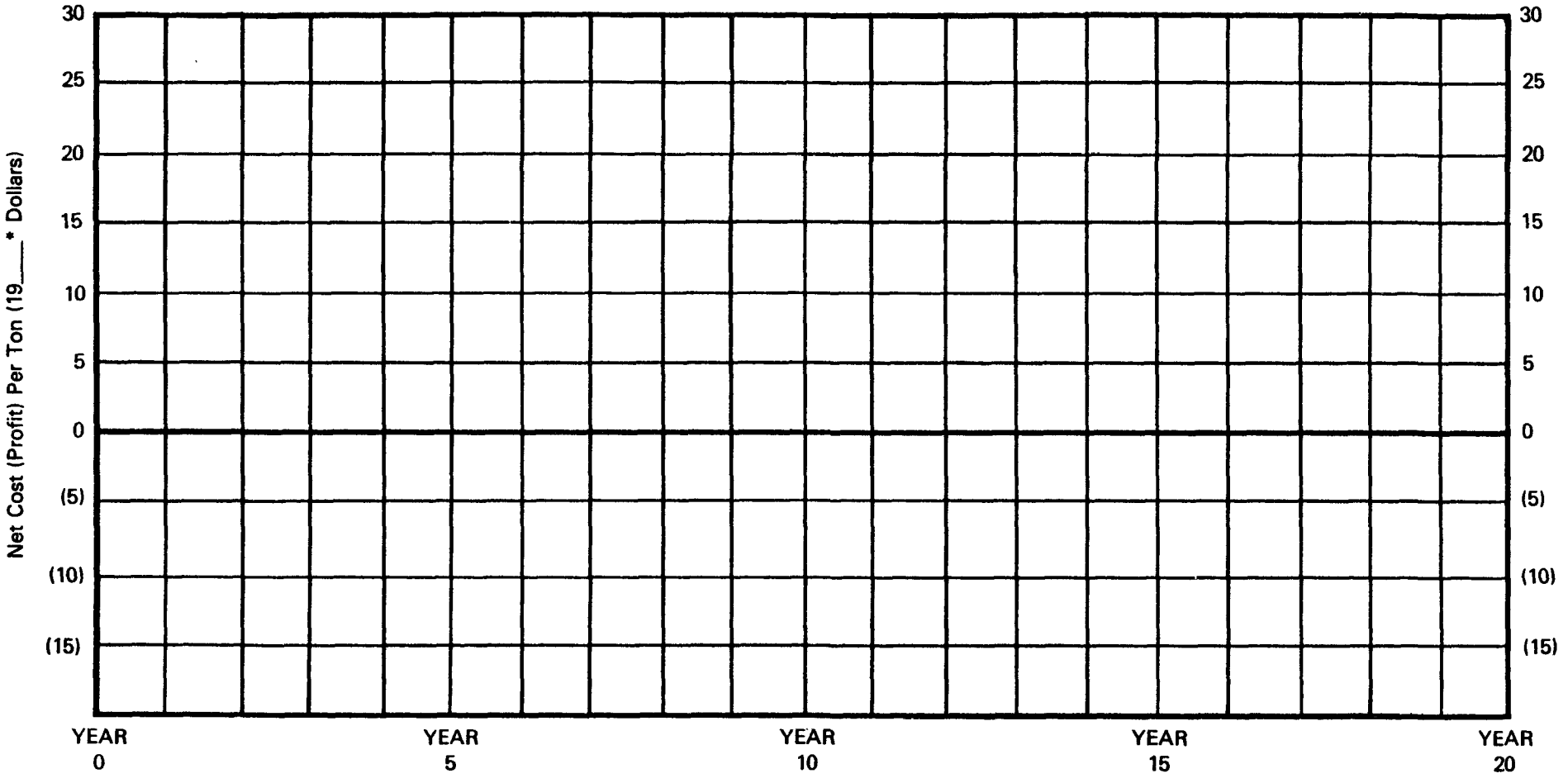
	Year 0	Year 5	Year 10	Year 15	Year 20
a. Debt Service	------	------	------	------	------
b. Annual O&M Costs	------	------	------	------	------
c. Landfill Cost (unprocessable waste)	------	------	------	------	------
d. Gross Annual Costs (Profit)	------	------	------	------	------
e. Steam Revenues	------	------	------	------	------
f. Electricity Revenues	------	------	------	------	------
g. Total Revenues	------	------	------	------	------
h. Net Annual Costs	------	------	------	------	------
i. Total Annual Waste Quantity (TPY)	------	------	------	------	------
j. Net Cost (Profit) Per Ton (Actual $)	------	------	------	------	------
k. Net Cost (Profit) Per Ton (Current $)	------	------	------	------	------

Analysis of Sensitivity to: _____

	Year 0	Year 5	Year 10	Year 15	Year 20
a. Debt Service	------	------	------	------	------
b. Annual O&M Costs	------	------	------	------	------
c. Landfill Cost (unprocessable waste)	------	------	------	------	------
d. Gross Annual Costs (Profit)	------	------	------	------	------
e. Steam Revenues	------	------	------	------	------
f. Electricity Revenues	------	------	------	------	------
g. Total Revenues	------	------	------	------	------
h. Net Annual Costs	------	------	------	------	------
i. Total Annual Waste Quantity (TPY)	------	------	------	------	------
j. Net Cost (Profit) Per Ton (Actual $)	------	------	------	------	------
k. Net Cost (Profit) Per Ton (Current $)	------	------	------	------	------

Worksheet Figure 13-1

Life Cycle Cost Comparison — Sensitivity Analysis



*Enter Current Year

APPENDIX B

POTENTIAL ENERGY MARKET QUESTIONNAIRE

POTENTIAL ENERGY MARKET QUESTIONNAIRE

From our initial information, it appears that you may be a potential user of energy product(s) produced by a solid waste resource recovery system. Please complete this questionnaire as comprehensively as possible, and return with any further information which you feel is pertinent. Your responses will be treated confidentially. Thank you for your assistance.

General Information

1. Name of Organization: _____

2. Address: _____

3. Telephone Number: _____

4. Name and Title of Person Completing Form: _____

_____

5. Type of Industry: _____

SIC Code: _____

6. Plant Operations - Shifts/Day: _____

Days/Week: _____

Weeks/Year: _____

Fuel Information

7. Please indicate average daily fuel usage by month plus annual totals:

	Coal (tons/day)	Oil (gals/day)	Gas (mcf/day)
January			
February			
March			
April			
May			
June			
July			
August			
September			
October			
November			
December			
Annual Total			

8. Please specify other fuel information:

	Natural Gas	Oil	Coal
Fuel Specifications			
Average Heat Content			
Fuel Costs			
Current Fuel Contracts (length, etc.)			
Average Annual Consumption (specify units)			

9. Please specify boiler information:

Number of Boilers
Capacity of Boilers
Age of Boilers
Steam Specifications (Temperature_____)
(Pressure_____)

10. Please indicate energy source used for following:

Space Heating:_____

Electricity Generation:_____

Manufacturing Process:_____

Refrigeration/Cooling:_____

Other:_____

11. Costs based on fuel costs: Steam: $ _____/1,000 lb.

Electricity: $ _____/KWH

12. Steam specifications

	Purpose	Temperature	Pressure	Percent of Total Use
a.				
b.				
c.				

13. Please specify steam requirements (indicate units):

	Average	Peak Demand	Weekend
January	_____	_____	_____
February	_____	_____	_____
March	_____	_____	_____
April	_____	_____	_____
May	_____	_____	_____
June	_____	_____	_____
July	_____	_____	_____
August	_____	_____	_____
September	_____	_____	_____
October	_____	_____	_____
November	_____	_____	_____
December	_____	_____	_____

14. Please specify electric power requirements (indicate units):

	Average	Peak Demand	Weekend
January	_____	_____	_____
February	_____	_____	_____
March	_____	_____	_____
April	_____	_____	_____
May	_____	_____	_____
June	_____	_____	_____
July	_____	_____	_____
August	_____	_____	_____
September	_____	_____	_____
October	_____	_____	_____
November	_____	_____	_____
December	_____	_____	_____

15. Please specify potential future increases or decreases in energy requirements. _____

_____

_____

_____

_____

_____

_____

_____