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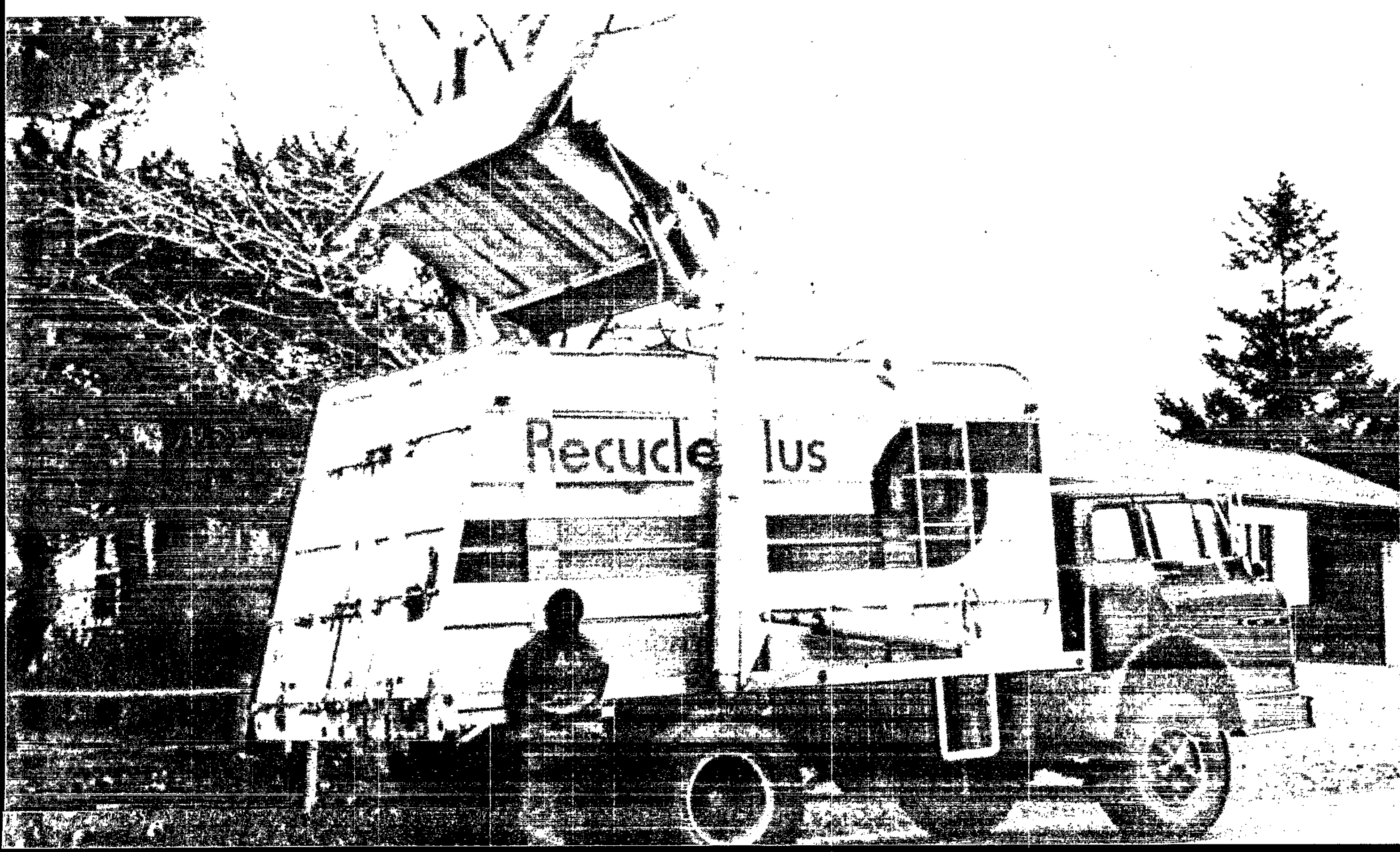
Multimaterial Source Separation in Marblehead and Somerville, Massachusetts

Energy Use and Savings from Source-Separated Materials and Other Solid Waste Management Alternatives for Marblehead

Volume IV



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MULTIMATERIAL SOURCE SEPARATION

IN MARBLEHEAD AND SOMERVILLE, MASSACHUSETTS

Energy Use and Savings from Source-Separated Materials and Other Solid Waste Management Alternatives for Marblehead

Volume IV

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MULTIMATERIAL SOURCE SEPARATION REPORT SERIES

This volume is one in a series of reports about the demonstration of multimaterial source separation in Marblehead and Somerville, Massachusetts. The series presents the key results of demonstration programs initiated and funded by the U.S. Environmental Protection Agency in 1975. Intended to provide local governments and the interested public with useful information for planning, implementing, and operating their own source separation programs, the reports in the series cover a range of issues related to source separation. The reports are:

The Community Awareness Program in Marblehead and Somerville, Massachusetts (SW-551)

Collection and Marketing (SW-822)

Composition of Source-Separated Materials and Refuse (SW-823)

Energy Use and Savings from Source-Separated Materials and Other Solid Waste Management Alternatives for Marblehead (SW-824)

Citizen Attitudes toward Source Separation (SW-825)

Any suggestions, comments, or questions should be directed to the Resource Recovery Branch (WH-563), Office of Solid Waste, U.S. Environmental Protection Agency, Washington, D.C. 20460.

Resource Planning Associates, Inc. conducted the studies and prepared this series under contract no. 68-01-3964.

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Introduction

Sanitary landfilling has traditionally been the method most widely used by municipalities to dispose of their solid waste. Over the last decade, however, increasingly stringent environmental regulations have restricted the number of sites available for landfilling, while municipal solid waste streams have been growing in volume. Consequently, many municipalities are investigating other disposal systems, many of which involve recovering and recycling some components of the waste or burning the waste to supply energy for various uses. In selecting a waste disposal system, municipalities usually consider the capital costs, labor costs, land-use requirements, and potential environmental effects of competing systems. These are, and are likely to remain, the decisive factors; however, as the need to conserve energy increases, municipalities are also comparing the energy expended in operating a system to the energy that can be extracted from the waste.

Early in 1976, the U.S. Environmental Protection Agency (EPA) awarded 3-year grants to the communities of Marblehead and Somerville, Massachusetts, to demonstrate the source separation of paper, cans, and glass by residents. For the first 2 years of the grants, the communities commissioned Resource Planning Associates, Inc. (RPA), to assist them in designing and implementing their programs. For the third grant year, EPA engaged RPA to assess the results of the two programs and to study the characteristics of the communities' residential waste streams.

EPA has commissioned RPA to conduct studies and prepare a series of reports about the two demonstration programs. The reports concern the collection and marketing of source-separated materials, citizen attitudes toward source separation, the composition of the source-separated materials and refuse, the energy use and savings from source separation and other solid waste management alternatives, and the community awareness programs developed to encourage participation in the source-separation programs.

This report presents our study of the energy use and savings from Marblehead's existing solid waste program, in which 25 percent of the waste stream is source-separated and processed. Energy is used in the existing source-separation program in the form of electricity, gasoline, or diesel fuel expended in handling and disposing of wastes and recovery materials. Energy is saved by recycling materials or generated by using materials in energy-recovery systems.

The report also presents our findings on energy use and savings for three solid waste management alternatives that Marblehead could pursue. In the first alternative, all waste would be transported to an energy-recovery facility near Marblehead and burned in a waterwall combustion unit to produce steam for an industrial plant. Noncombustible residual waste from the unit would be landfilled at the incinerator site. In the second, all solid waste would be hauled to the Marblehead solid waste transfer station and from there to the regional landfill. The third alternative is a combined system of source separation and energy recovery at different rates of source separation: 12.5 percent of total waste; Marblehead's current recycling rate of 25 percent; and a theoretical maximum of 40 percent.

To calculate energy use and savings, we separated the existing and alternative systems into four independent steps:

- Collection, which comprises collecting waste materials from curbside and hauling them in recycling trucks or refuse trucks to a processing or preparation site
- Preparation, which comprises sorting, crushing, shredding, baling, and compacting waste materials to prepare them for reuse or transportation to landfill sites
- Transportation, which comprises hauling processed waste from preparation sites to treatment sites in heavy-duty tractor-trailer trucks

- Treatment, which comprises reusing wastes in a manufacturing process, burning them to recover energy, or landfilling.

We calculated the direct energy use and savings from each step independently by considering such factors as energy directly consumed by machinery and lighting, energy directly conserved by substituting recycled materials for virgin raw materials, and energy directly generated by using solid waste for fuel to produce steam. For practical reasons, we did not calculate indirect energy expenditures, such as energy consumed in manufacturing the equipment used by the systems.

We then computed net energy use and savings per ton of total solid waste (source-separated materials and remaining waste). We found that:

- Marblehead's existing source-separation program returns about 1.6 million Btu/ton of total solid waste, which is equivalent to about 12.8 gallons of gasoline per ton.

- Of the disposal alternatives, the combined source-separation/energy-recovery system with a 40-percent source-separation rate had the highest energy return of 7.7 million Btu/ton. In Marblehead, source separation increases the total energy savings because recycling noncombustible materials such as glass and cans saves energy that cannot be used by energy-recovery systems.

- Energy recovery of all wastes would return about 6.3 million Btu/ton

- Landfill disposal of all wastes would use about 0.4 million Btu/ton.

In Chapter 1, we discuss our calculations of energy use and savings for each step of Marblehead's existing solid waste management program. In Chapter 2, we discuss the calculations we performed for each solid waste management alternative. Appendix A provides additional background on Marblehead's solid waste and source-separation programs.

Exhibit 1.a

Energy Used And Saved In Marblehead's Existing Solid Waste Program
(10 3 Btu/ton)

	Energy Used	Energy Saved	Total
Collection			
Recovered paper, glass, and cans	96	—	
Remaining waste	131	—	
Subtotal	227		
Preparation			
Recovered glass and cans	15	—	
Recovered paper	70	—	
Remaining waste	70	—	
Subtotal	162	—	(162)
Transportation			
Recovered glass	40	—	
Recovered cans	47	—	
Recovered paper	18	—	
Remaining waste	116	—	
Subtotal	221	—	(221)
Treatment			
Recovered glass	—	770	
Recovered cans	—	376	
Recovered paper	—	1,103	
Remaining waste	44	—	
Subtotal	44	2,249	2,205
Total	**654**	**2,249**	**1,595**

SOURCE: Resource Planning Associates, Inc.
NOTE: Parentheses indicate net energy use.

Exhibit 2.a

Energy Used and Saved in Marblehead's Solid Waste Disposal Alternatives
(103 Btu/ton)

	Energy Recovery	Source Separation/ Energy Recovery System: 12.5% Rate	25% Rate	40% Rate	Landfill Disposal
Collection	(224)				(224)
Preparation	(103)	(132)	(161)	(197)	(103)
Transportation	(52)	(108)	(144)	(199)	(52)
Treatment	6,678	7,486	8,005	8,323	(59)
Total	**6,299**	**7,046**	**7,473**	**7,669**	**(438)**

SOURCE: Resource Planning Associates, Inc.
NOTE Parentheses indicate net energy use.

1 ENERGY USE AND SAVINGS FROM MARBLEHEAD'S EXISTING SOLID WASTE MANAGEMENT PROGRAM

The reuse of materials from Marblehead's source-separation program conserves about 3.5 times as much energy as is used by the town's entire solid waste collection and disposal operations (see Exhibit 1.a). About 2.25×10^6 Btu/ton is saved by source separation, while about 0.65 Btu/ton is used by equipment for collection, preparation, transportation, and treatment of source-separated materials and remaining waste. The resulting net energy savings from Marblehead's existing program are about 1.6 million Btu/ton of solid waste, or savings the equivalent of 0.29 barrels of oil per ton. For Marblehead's total solid waste stream of about 8,700 tons per year, 2,530 barrels of oil are conserved from the existing program of source separation and landfilling of remaining waste.

Collection and transportation equipment use more energy than equipment used to prepare or treat source-separated materials and remaining waste. Collection consumes about 35 percent of the energy used, and transportation 34 percent.

COLLECTION

All of Marblehead's source-separated materials and remaining waste are collected on different days at curbside once per week. Source-separated materials are taken directly to a materials processor in Salem, Massachusetts, less than 5 miles away, while remaining waste is delivered to a transfer station in Marblehead.

Two gasoline-powered trucks that can carry about four tons of materials each are used to collect source-separated materials. The trucks have separate compartments for paper, clear glass and cans, and colored glass and cans. Fuel consumption for the source-separation vehicles, as reported in town records, is 3.09 gallons per ton of recovered materials collected, or $386x10^3$ Btu/ton. During July and August 1977, 892 gallons of gasoline were used in collecting 289 tons of source-separated materials (1 gallon of gasoline equals $125x10^3$ Btu).

The town has three diesel-powered standard 18-cubic-yard compactors to collect remaining waste. Fuel consumption for the vehicles is 1.25 gallons per ton of remaining waste or $175x10^3$ Btu/ton. During July, August, and September 1977, 2,083 gallons of fuel were used in collecting 1,667 tons of refuse (1 gallon of diesel fuel equals $139x10^3$ Btu).

Of the total solid waste stream, 25 percent is collected by source-separation vehicles and 75 percent is collected by refuse trucks. Therefore, the energy used for collection per ton of solid waste may be calculated as follows:

$$(386x10^3 \text{ Btu/tons of source-separated materials } x \frac{25}{100})$$

$$+ (174x10^3 \text{ Btu/ton of remaining waste } x \frac{75}{100})$$

$$= (96 + 131) \times 10^3 \text{ Btu/ton}$$

$$= 227x10^3 \text{ Btu/ton of total solid waste.}$$

PREPARATION

Energy is used to prepare source-separated materials, such as paper and glass and cans, at the materials processing plant in Salem. The energy used to prepare remaining waste is expended at Marblehead's transfer station.

Recyclable glass and cans are delivered to MATCON Recycling, Inc., in Salem. Two small front-end loaders transfer the materials from the point of delivery to a conveyor belt, leading to a magnetic drum where the ferrous materials are separated.* They are then flattened by one of the front-end loaders in preparation for transportation to a buyer. Glass is conveyed through a hammermill, broken into approximately 2-inch cullet, and stored in large bins before transportation.

The front-end loaders are operated on gasoline and propane. All other equipment, heating, and lighting are operated by electricity.

During October 1977, MATCON prepared 932 tons of glass and cans, using 2,700 kWh of electricity, 584 gallons of gasoline, and 104 gallons of propane.[1] The thermal value of propane is 73,390 Btu/gallon. The energy used per ton of glass and cans may then be calculated as follows:

$$(2{,}700 \text{ kWh} \times 10{,}286 \text{ Btu/kWh}) + (584 \text{ gal} \times 125\times10^3 \text{ Btu/gal gasoline}) + (104 \text{ gal} \times 73{,}390 \text{ Btu/gal propane gas} \div 932 \text{ tons} = 116\times10^3 \text{ Btu/ton.}$$

Recycled paper is delivered to Northshore Recycled Fibers, Inc., in Salem. The paper is dumped onto the warehouse floor and pushed into a large shredder by two small gasoline-fueled front-end loaders. The shredded paper is conveyed to a baling machine, baled, and loaded on a truck by the front-end loaders. All equipment except the loaders is powered by electricity. The loaders are in operation approximately 6 hours per day, using 2.5 gallons of gasoline per hour.[2]

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1. Personal communications from John Clement, MATCON Recycling, Inc.

2. Personal communications from Mr. Patrick Scanlon, Northshore Recycled Fibers, Inc., and Mr. Paul Anderson, Clark Equipment Company, Fargo, North Dakota.

* Aluminum constitutes less than 1 percent of the recyclable waste stream in Marblehead and is not accounted for in our calculations.

Approximately 11 tons of paper are processed per hour.[3] Consequently 0.22 gallons are consumed per ton processed. The energy used by the loaders is:

0.22 gal/ton x 125×10^3 Btu/gal = 28×10^3 Btu/ton.

No data were available on the operation or energy consumption of the Northshore Recycling equipment. However, similar equipment consumes 50 kWh of electricity to compact and bale 1 ton of paper.[4]

The energy used for shredding and baling may then be calculated as follows:

50 kWh/ton x 10,286 Btu/kWh = 514×10^3 Btu/ton.

The total figure for paper is:

(28 + 514) x 10^3 Btu/ton of paper = 542×10^3 Btu/ton of paper).

All remaining waste in Marblehead's existing program is delivered to the Marblehead transfer station, reduced to one-seventh of its original volume in a compactor, and loaded in a heavy-duty truck for further transportation. All equipment at the station is powered by electricity.

Electricity for heating, lighting, and operating of equipment costs approximately $300 per month, representing an average of 13,300 kWh consumed per month at local commercial rates to process 1,330 tons of

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3. EPA, Demonstrating Source Separation in Somerville and Marblehead (draft), February 1977, pp. 4-6.

4. EPA, Environmental Impacts of Production of Virgin and Secondary Paper, Glass and Rubber Products. This figure does not include electricity for lighting or administrative offices.

waste.[5] The fuel-fired value of purchased electricity is 10,286 Btu/kWh.[6] The energy expenditure for preparation of remaining waste is therefore:

$$\frac{13{,}300\ \text{kWh}}{1{,}300\ \text{ton}} \times 10{,}286\ \text{Btu/kWh} = 103\text{x}10^3\ \text{Btu/ton.}$$

Of the total solid waste stream, 12 percent is recovered glass and cans, 13 percent is recovered paper, and 75 percent is remaining waste. Therefore, the energy used to prepare all solid waste is calculated as follows:

$$(116\text{x}10^3\ \text{Btu/ton of glass and cans} \times \frac{12}{100}) + $$

$$542\text{x}10^3\ \text{Btu/ton of paper} \times \frac{13}{100}) + 103\text{x}10^3\ \text{Btu/ton}$$

$$\text{of remaining waste} \times \frac{75}{100})$$

$$= (15 + 70 + 77) \times 10^3\ \text{Btu/ton}$$

$$= 162\text{x}10^3\ \text{Btu/ton of total solid waste.}$$

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5. Personal communications from Mr. Charles Eris at Service Corporation of American (SCA), operators of the station, and Mr. Frank Stevenson, Marblehead transfer station. Electricity rates are $1.60/kWh for the first 20 kWh; $0.67/kWh for the next 100 kWh; $0.37 kWh for the next 590 kWh; and $0.19 kWh for all additional kWh.

6. U.S. Federal Energy Administration, <u>The Data Base: The Potential for Energy Conservation in Nine Selected Industries</u>, 1975, vol. 8: p. 6. This value accounts for boiler inefficiency and transmission losses.

TRANSPORTATION

In the transportation step, source-separated glass, cans, and paper are shipped to their final markets and remaining waste is transported from the transfer station to the regional landfill. Source-separated material and remaining waste are hauled in heavy-duty, diesel-fueled trucks. To simplify calculations, we assumed that twice as much fuel is consumed by trucks when fully loaded as when returning empty.[7] We also assumed that the trucks all consume $3.45\text{x}10^3$ Btu/ton-mile, even though they are used to haul different materials.

Remaining waste is hauled from the transfer station to the regional landfill in Amesbury, Massachusetts, 30 miles away. Therefore, energy used to transport remaining waste is calculated as follows:

$3.45\text{x}10^3$ Btu/ton-mile x 30 miles/trip x 1.5 trips

= $155\text{x}10^3$ Btu/ton.

Source-separated glass cullet is shipped from MATCON to Dayville, Connecticut, approximately 80 miles from Salem. The energy used to transport recycled glass is:

$3.45\text{x}10^3$ Btu/ton-mile x 80 miles/trip x 1.5 trips

= $414\text{x}10^3$ Btu/ton.

Prepared cans are transported to Newark, New Jersey, for detinning and from there to Pittsburgh for reuse, a total distance of 590 miles. We assumed that the trucks return fully loaded. The energy used to transport recycled cans can therefore be calculated as follows:

$3.45\text{x}10^3$ Btu/ton-mile x 590 miles/trip = $2{,}035\text{x}10^3$

Btu/ton.

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7. Portland Recycling Team, Resource Conservation Through Citizen Involvement in Waste Management: Report to the Metropolitan Service District, 1975.

Baled waste paper is shipped from Northshore Recycled Fibers to a papermill at Haverhill, Massachusetts, a distance of 27 miles. The energy used to transport recycled paper is therefore:

3.45×10^3 Btu/ton-mile x 27 miles/trip x 1.5 trips

= 140×10^3 Btu/ton.

Of the total solid waste stream, about 9.7 percent is recovered glass, about 2.3 percent is recovered cans, 13 percent is recovered paper, and 75 percent is remaining waste.

Therefore, the energy used to transport all solid waste is computed as follows:

$$(414 \times 10^3 \text{ Btu/ton of glass} \times \frac{9.7}{100}) + (2{,}035 \times 10^3 \text{ Btu/ton of cans} \times \frac{2.3}{100}) + (140 \times 10^3 \text{ Btu/ton of paper} \times \frac{13}{100}) + (155 \times 10^3 \text{ Btu/ton of remaining waste} \times \frac{75}{100})$$

$$= (40 + 47 + 18 + 116) \times 10^3 \text{ Btu/ton}$$

$$= 221 \times 10^3 \text{ Btu/ton of total solid waste.}$$

TREATMENT

Treatment of solid waste consists of converting the recovery materials into new products and landfilling the remaining waste. Energy is saved by reprocessing recovered materials, which uses less energy than mining, milling, or manufacturing products from virgin materials.

About 3,970x10^3 Btu of energy is conserved by producing 1 ton of glass containers from a 50-percent mixture of recycled glass cullet and virgin materials.[8] Therefore, each ton of recycled glass cullet used saves 7,940x10^3 Btu.

Manufacturing pig iron from recovered cans conserves 16,340x10^3 Btu per ton of iron produced, compared to the manufacture of pig iron from virgin materials.[9] This excludes the energy used during preliminary detinning, for which data were not available. Detinning uses less energy than making tin from virgin materials. However, since the amount of tin in ferrous metal cans is small compared to the amount of iron, the energy saved by detinning would also be small.

Recovered paper from Marblehead is converted into corrugated containers. About 4,888x10^3 Btu per ton of manufactured corrugated containers is conserved if recovery paper is used rather than virgin materials.[10] One ton of recovered paper is used to produce 1.74 tons

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8. EPA, Environmental Impacts of Production of Paper, Glass, and Rubber Products, pp. 149-150.

9. FEA, The Data Base, 1975, pp. 342-345. No difference in energy use was assumed among steelmaking processes or input materials.

10. EPA, Environmental Impacts of Production of Paper, Glass and Rubber Products, p. 77. The production of corrugated containers from virgin materials uses 23,800x 10^3 Btu, including harvesting, transportation, and conversion of pulpwood. No energy savings are realized from the actual milling operations in making corrugated containers from recovered paper. Milling packaging paperboard, printing paper, and tissue paper from recovered paper would conserve an additional 4,000x10^3 Btu/ton, 5,000x10^3 Btu/ton, and 11,000x10^3 Btu/ton, respectively.

of corrugated containers, so the energy conserved per ton of waste paper may be calculated as follows:

$4,888 \times 10^3$ Btu/ton of corrugated containers x 1.74 ton of corrugated containers/ton of recovered paper

= $8,486 \times 10^3$ Btu/ton of recovered paper.

Marblehead's remaining waste is treated simply by landfill disposal, which uses energy in the form of diesel fuel to power the bulldozer that spreads and covers waste; we estimated that 59×10^3 Btu are used per ton of remaining waste.[11]

The composite energy saved in treatment processes for all solid waste is as follows:

$$(7,940 \times 10^3 \text{ Btu/ton of glass} \times \frac{9.7}{100}) + 16,340 \text{ Btu/ton of cans} \times \frac{2.3}{100}) + (8,486 \text{ Btu/ton of paper} \times \frac{13}{100})$$

$$- 59 \times 10^3 \text{ Btu/ton of remaining waste} \times \frac{75}{100})$$

$$= (770 + 376 + 1,103 - 44) \times 10^3 \text{ Btu/ton}$$

$$= 2,205 \text{ Btu/ton.}$$

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11. Portland Recycling Team, Resource Conservation Through Citizen Involvement, p. 128.

Exhibit 2.b

Energy Used and Saved in Combined Source Separation and Energy Recovery System
(10^3 Btu/ton)

	Source Separation Rates		
	12.5%	25%	40%
Collection			
Recovered paper, glass and cans	(48)	(96)	(154)
Remaining waste	(152)	(131)	(104)
Subtotal	(200)	(227)	(258)
Preparation			
Recovered glass and cans	(7)	(14)	(22)
Recovered paper	(35)	(70)	(113)
Remaining waste	(90)	(77)	(62)
Subtotal	(132)	(161)	(197)
Transportation			
Recovered glass	(20)	(40)	(64)
Recovered cans	(34)	(47)	(75)
Recovered paper	(9)	(18)	(29)
Remaining waste	(45)	(39)	(31)
Subtotal	(108)	(144)	(199)
Treatment			
Recovered glass	385	770	1,231
Recovered cans	270	376	605
Recovered paper	552	1,103	1,765
Remaining waste	6,279	5,756	4,722
Subtotal	7,486	8,005	8,323
Total	**7,046**	**7,473**	**7,669**

SOURCE: Resource Planning Associates, Inc.

NOTE: Parentheses indicate net energy use.

Using Marblehead as a base case, we examined the energy used and savings from three solid waste disposal alternatives: recovering energy through a mixed-waste processing system; a combination of source separation and energy recovery from remaining waste; and landfill disposal of all solid wastes. We examined the combined system at source-separation rates of 12.5, 25, and 40 percent of total wastes.

The combined system with a source-separation rate of 12.5 percent would have a net energy savings of 7.0 million Btu/ton, which is higher than the energy-recovery alternative which would save 6.3 million Btu/ton. The combined system with a 40-percent source-separation rate would have the highest energy savings of all the alternatives: 7.7 million Btu/ton. The combined system with 25-percent source separation would yield an energy savings of 7.5 million Btu/ton. In contrast, landfill disposal of all waste would use 0.4 million Btu/ton, which is equivalent to using about 2.3 gallons of gasoline per ton (see Exhibit 2.a).

ENERGY RECOVERY SYSTEM

To calculate the amount of energy that would be saved using an energy-recovery system, we assumed that waste is collected at curbside and delivered to the transfer station in Marblehead. Before the source-separation program began in Marblehead, all solid waste was collected by five compactor vehicles twice per week. Records on energy consumption for that period were not available. However, we assumed that twice-per-week collection uses 29 percent per ton more energy than

Marblehead's current once-per-week collection.[1] Therefore, energy consumption for twice-per-week collection is computed as follows:

174×10^3 Btu/ton of solid waste x 1.29

= 224×10^3 Btu/ton of solid waste.

The waste would then be prepared at the transfer station using the same amount of energy as Marblehead's existing system: 103×10^3 Btu per ton of waste.

Prepared waste would be transported from the Marblehead transfer station to an energy-recovery plant in Saugus, Massachusetts, 10 miles away. The energy used in transporting waste to the plan may therefore be calculated as follows:

3.45×10^3 Btu/ton-mile x 10 miles/trip x 1.5 trips

= 52×10^3 Btu/ton.

In the energy-recovery system, all prepared waste would be delivered to the Saugus facility, dumped into a large storage pit, and fed into a large waterwall combustion chamber where it would be burned to produce steam at a temperature of 875°F and a pressure of 690 psig.[2] We assumed a boiler efficiency, less steam transmission losses, for waterwall incineration of 67 percent.[3] Noncombustible residue would be landfilled at the site. The thermal value of refuse in Marblehead

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1. Kenneth A. Shuster, "Fuel Conservation in Solid Waste Management," Virginia Town and City, December 1974.

2. U.S. Department of Energy, Overcoming Institutional Barriers to Solid Waste Utilization as an Energy Source, November 1977, p. 28.

3. Oak Ridge National Laboratory, Solid Waste Utilization Incineration with Heat Recovery, April 1978, p. 9. Boiler efficiency is 69 percent, transmission losses are 2 percent.

is 4,340 Btu/lb.[4] At the specified boiler efficiency and steam temperature and pressure, the thermal value of the steam would be:

$$4{,}340 \text{ Btu/lb} \times 2{,}000 \text{ lb/ton} \times \frac{67}{100} = 5{,}816\text{x}10^3 \text{ Btu/ton.}$$

Steam would be delivered to an industrial plant, one-third of a mile from the facility. If the same quantity of steam at the same temperature and pressure were raised on-site in an oil-fired boiler with an efficiency of 82 percent, the energy saved would be:

$$5{,}816\text{x}10^3 \text{ Btu/ton} \times \frac{82}{100} = 7{,}093\text{x}10^3 \text{ Btu/ton.}$$

In June 1977, the Saugus plant consumed 1,210 MWh of electricity per month for lighting, heating, and operation of electric power equipment, and 1,497 gallons of diesel fuel and 34 gallons of gasoline for mobile equipment.[5] The energy expenditure may therefore be calculated as follows:

(1,210x10^3 kWh/month x 10,286 Btu/kWh) + (1,497 gal of diesel fuel/month x 139x10^3 Btu/gal of diesel fuel) + (34 gal of gasoline/month x 125x10^3 Btu/gal of gasoline) $\div$ 30,517 ton of waste/month = 415x10^3 Btu/ton.

4. EPA, Multimaterial Source Separation in Marblehead and Somerville, Massachusetts: Composition of Source Separated Materials and Refuse, November 1978, p. 28.

5. Personal communications with the general manager of the operating contractor of the Saugus facility.

The net energy savings for treatment in the energy-recovery system are therefore:

$7{,}093 \times 10^3$ Btu/ton - 415×10^3 Btu/ton = $6{,}678 \times 10^3$

Btu per ton.

COMBINED SOURCE-SEPARATION/ENERGY-RECOVERY SYSTEM

The highest energy savings would be achieved by combining source separation and energy recovery. For this alternative, we assumed that the source-separation system is the same as the one currently used. However, we assumed three different rates of recovery: 12.5 percent of the total waste stream; the present rate of 25 percent; and the theoretical maximum rate of 40 percent. We assumed that energy would be recovered at a rate similar to the one already calculated in our energy-recovery alternative.

Source-separated materials and remaining waste would be collected once per week. To estimate the amount of fuel used in collection, we assumed that fuel consumption rates per ton would be the same for different rates of source separation. In reality, however, fuel consumption rates would probably be slightly lower for higher rates of source separation. We used the same fuel consumption rates for source-separated materials and remaining waste as for the existing program. Therefore, fuel consumption for the 12.5-percent source-separation rate is calculated as follows:

386×10^3 Btu/ton of source-separated materials $\times \frac{12.5}{100}$

$+ 174 \times 10^3$ Btu/ton of remaining waste $\times \frac{87.5}{100}$

$= (48 + 152) \times 10^3$

$= 200 \times 10^3$ Btu/ton of total solid waste.

Similarly computed for 25-percent and 40-percent source-separation rates, fuel consumption rates for collection are 227×10^3 Btu/ton and 258×10^3 Btu/ton, respectively.

We calculated the energy used to prepare and transport source-separated materials and the energy saved by treating the materials on the basis of our calculations for Marblehead's existing program. Energy used and recovered from materials at a 25-percent rate of source separation was the same as for the existing program; for a 12.5-percent rate, energy used and savings were half of those for the existing program; and for a 40-percent rate, energy used and savings were computed to be 1.6 times the results from the existing program.

To compute the energy used to prepare and transport remaining waste for different levels of source separation, we again used the energy use per ton of remaining waste from the existing program and multiplied that unit rate by the percent of remaining waste, 87.5, 75, or 60 percent, in the total solid waste stream for that option (see Exhibit 2.b).

The thermal value of Marblehead's remaining waste after 25 percent of the waste is source-separated is $4{,}950 \times 10^3$ Btu/lb.[6] The thermal value of remaining waste without source separation is 4,340 Btu/lb. Assuming a linear relationship between thermal values and source-separation rates, we calculated the thermal value of remaining waste for 12.5-percent and 40-percent source-separation rates to be 4,645 Btu/lb and 5,070 Btu/lb, respectively.

Using an estimated efficiency for the steam boiler and transmission losses of 67 percent and an oil-fired

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6. EPA, Multimaterial Source Separation in Marblehead and Somerville, Massachusetts: Composition of Source Separated Materials and Refuse, November 1978, p. 28.

boiler efficiency of 82 percent, the energy saved by treating the remaining waste at a 12.5-percent rate of source separation is computed as follows:

$$4{,}645\text{x}10^3 \text{ Btu/lb x } 2{,}000 \text{ lb/ton x } \frac{67}{100} \text{ x } \frac{100}{82} \text{ x } \frac{87.5}{100} = 6{,}642\text{x}10^3 \text{ Btu/ton of total solid waste.}$$

Similarly, the energy savings for 25-percent and 40-percent source-separation rates were computed to be $6{,}067\text{x}10^3$ Btu/ton and $4{,}971\text{x}10^3$ Btu/ton, respectively.

We assumed that energy use in the energy-recovery plant operations would be the same per ton of remaining waste as for the energy-recovery alternative: $415\text{x}10^3$ Btu/ton. Therefore, the net energy savings per ton of total solid waste in the energy recovery operations are as follows:

$$6{,}642\text{x}10^3 \text{ Btu/ton} - \frac{87.5}{100} \text{ x } 415\text{x}10^3 \text{ Btu/ton} = 6{,}279\text{x}10^3 \text{ Btu/ton}$$

12.5-percent source separation;

$$6{,}067\text{x}10^3 \text{ Btu/ton} - \frac{75}{100} \text{ x } 415\text{x}10^3 \text{ Btu/ton} = 5{,}756\text{x}10^3 \text{ Btu/ton}$$

25-percent source separation;

$$4{,}971\text{x}10^3 \text{ Btu/ton} - \frac{60}{100} \text{ x } 415\text{x}10^3 \text{ Btu/ton} = 4{,}722\text{x}10^3 \text{ Btu/ton}$$

40-percent source separation.

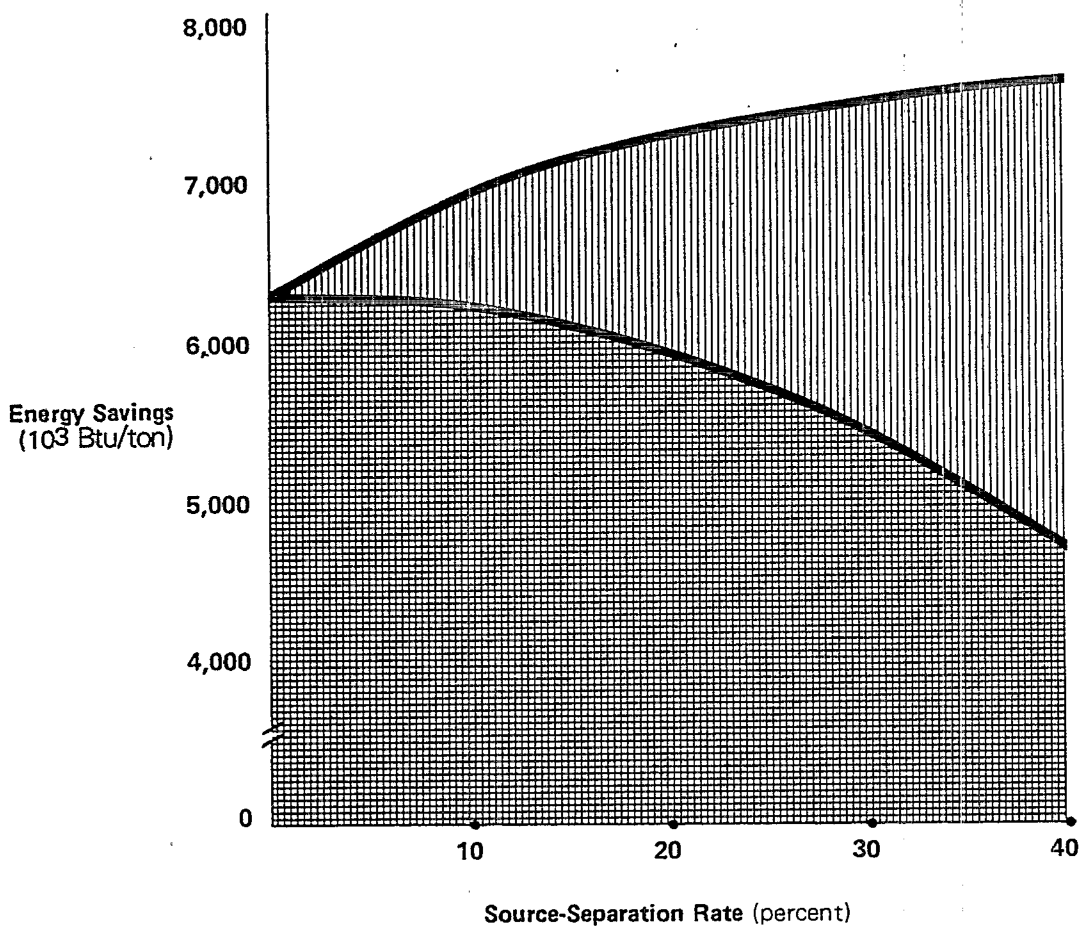
Total net energy savings increase as the percentage rate of source separation increases, as shown in Exhibit 2.c. As more materials are source-separated, the energy savings attributed to energy recovery decrease since fewer materials are processed in the energy-recovery facility.

LANDFILL DISPOSAL

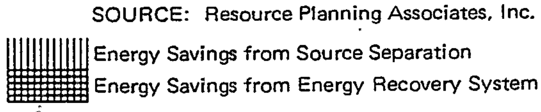
Energy used to collect and prepare total solid waste for landfill disposal is the same as for the energy-recovery alternative: 224×10^3 Btu/ton for collection and 103×10^3 Btu/ton for preparation. All solid waste would then be transported to the landfill in Amesbury, 30 miles away. The energy use per ton of waste is therefore the same as for Marblehead's existing program: 52×10^3 Btu/ton of refuse. Energy used in treatment is also the same for this alternative as for Marblehead's existing program: 59×10^3 Btu per ton of refuse. The total energy used for landfill disposal of solid waste is therefore 438×10^3 Btu/ton.

Exhibit 2.c

Energy Savings for Combined Source Separation and Energy-Recovery System



SOURCE: Resource Planning Associates, Inc.



PROGRAM BACKGROUND

As part of its evaluation of different types of resource-recovery programs, EPA selected Somerville and Marblehead, Massachusetts, for demonstration studies of source separation. This appendix provides demographic information about Marblehead and summarizes how its source-separation program operates.

DEMOGRAPHIC INFORMATION

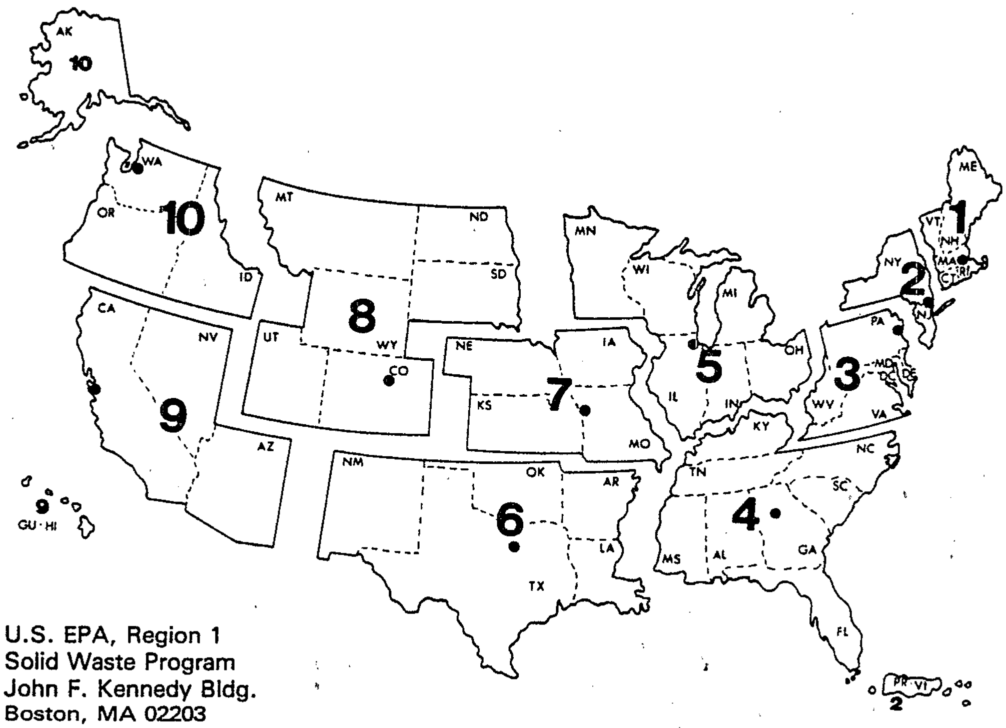
Marblehead is an affluent suburban community in the Boston metropolitan area with a population of 23,000 and a density of 5,200 persons per square mile. Seventy percent of the families live in single-family homes. Fifteen percent of the families rent their homes or apartments, and 85 percent own their residences. The U.S. Bureau of the Census listed the 1970 median income for Marblehead as $12,600 per year, and the median education level as 13.2 years.

For the source-separation program in Marblehead, residents place three bundles -- flat paper, clear glass and cans, and colored glass and cans -- at the curb for collection on source-separation days, which are different than regular trash collection days. As in Somerville, no other preparation is necessary. Special crews with three-compartment trucks pick up the materials. In addition to the weekly collection of source-separation materials, Marblehead has open bins at the site of the former town landfill for residents who wish to bring their materials. The success of Recycle Plus helped the town to reduce the frequency of the remaining mixed household refuse collection from twice per week to once per week. The town also was able to reduce its mixed-refuse equipment and labor needs.

Salient features of Marblehead's program can be summarized as follows:

Program name	"Recycle Plus"
Materials collected	Flat paper Cans and clear glass Cans and colored glass
Recyclables collection frequency	Weekly
Refuse collection frequency	Weekly
Recycling crews	Two 3-man crews
Refuse crews	Four 3-man crews
Collection vehicles	Compartmentalized trucks with rear-loading hydraulic buckets; 3 compartments
Disposal cost per ton	$18.95

EPA REGIONS



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