ENERGY CONSERVATION

THROUGH IMPROVED SOLID WASTE MANAGEMENT

This report (SW-125) was written
by ROBERT A. LOWE
with appendices by MICHAEL LOUBE and FRANK A. SMITH

U.S. ENVIRONMENTAL PROTECTION AGENCY
1974

ENERGY CONSERVATION
THROUGH IMPROVED SOLID WASTE MANAGEMENT (SW-125)
Update Sheet
September 1976

SW125

The above report published by EPA in 1974, should now be updated on the pages indicated by the following information.

Page 12, replace Table 2 with the following:

Table 2
ENERGY POTENTIALLY RECOVERABLE FROM WASTE*

	1973			1973		
	Btu's+ (trillion)	B/DOE# (thousand)	B/YOE# (million)	Btu's (trillion)	B/DOE (thousand)	B/YOE (million)
Theoretical	1,194	564	206	1,440	680	248
Available	899	424	154	1,085	512	187
Projected Implementations	-----	---	---	85	40	15

*These estimates of the amount of energy that could be recovered from residential and commercial waste are a function of (1) population; (2) the average amount of residential and commercial solid waste generated per person, and (3) the energy content of residential and commercial solid waste (4500 Btu per pound. The higher heating value of 4500 Btu per pound (9 million Btu per ton) is generally accepted as the energy value of "as received," unprocessed waste as delivered by a collection truck to a processing or disposal facility.

+Btu: British Thermal Unit.
#B/DOE: Barrels per day of oil equivalent. (Assuming 5.8 million Btu's per barrel of oil and 365 days per year.) B/YOE: Barrels per year of oil equivalent.
Based on all Standard Metropolitan Statistical Areas (SMSA's).

NOTE: Different waste processing methods have different recovery efficiencies. For example, a shredding/air classification waste processing system loses some potential energy by removing heavy combustibles from the fuel fraction, while high temperature incineration with no prior classification would lose far less potential energy. However, no adjustment was made to allow for such processing looses or energy conversion efficiencies (of, say, steam or electricity) because no prejudgment can be made as to which energy recovery method would be used in any given situation.

Page 14, paragraph 1: Delete and substitute the following:

At the present time, energy is being recovered from post-consumer solid waste in the following locations in the United States:

Ames, Iowa (RDF)
Blytheville, Arkansas (Small incineration)
East Bridgewater, Mass. (RDF)
Groveton, N.H. (Small incineration)
Harrisburg, Penn. (Waterwall combustion)
Nashville, Tenn. (Waterwall combustion)
Norfolk, Va. (U.S. Naval base; waterwall combustion)
Palos Verdes, Calif. (Methane recovery)
St. Louis, Mo. (EPA demonstration; RDF)
Saugus, Mass. (Waterwall combustion)
Siloam Springs, Arkansas (Small incineration)
South Charleston, W. Va. (Private test facility; pyrolysis)

Pages 15-19: Delete and substitute the following:

Due to the highly complex nature of implementing resource recovery, the criteria used here to project possible implementations are not really valid. Many cities that seem to have favorable local conditions -- economics, markets and public interest -- have encountered stumbling blocks that have delayed or postponed their projects. These obstacles may be legal, financial, or technical; or they may relate to the three criteria above.

Some cities do not have control over a sufficient amount of waste within an economical haul distance to make a facility viable. Other cities have procurement laws which limit their options for acquiring a contractor or negotiating a contract. Inability to bid design and construction activities as a single contract or to accept other than the lowest bid may prevent a city from obtaining the strongest possible guarantees or the "best" design and equipment.

The market criterion used here, the presence of an electric utility boiler with ash-handling capability, is not a valid determinant. Almost every area has a viable market: the electrical grid network.

The three economic criteria are also insufficient. More important than population size is population density and control of the waste stream. The community must be able to guarantee delivery of the waste to the resource recovery facility and the population must be sufficiently concentrated to collect and deliver large quantities within an economical distance.

The criterion of alternative disposal costs is also not valid. While the scarcity of land makes disposal more expensive, at the present time resource recovery prices are generally competitive with only distant landfills or those operating with the best environmental controls. Because of the continued rising cost of land and stricter environmental regulations regarding landfills, resource recovery should, in the future, be competitive with landfills in many areas. The advantage now of resource recovery over landfills is the conservation of landfill space and the "cleaner" quality of the residue.

For a description of current resource recovery activities in the United States, see: McEwen, L. A Nationwide Survey of Resource Recovery Activities. Environmental Protection Publication SW-142.1. Washington, U.S. Environmental Protection Agency, 1976. (In preparation.)

Page 21, paragraph 3: Add the following:

The Nashville waterwall combustion system was completed in mid-1974. However, because of deficiencies in the design, several costly modifications, most notably to the air pollution control equipment, will be made to the facility. In order to help cover operation costs and the capital costs of the necessary modifications, steam prices have doubled and the City will pay a dump fee.

Page I-3, paragraph 2: Delete sentence one and substitute the following:

EPA is partially funding two source separation demonstration projects in Somerville and Marblehead, Massachusetts. Residents separate their household refuse into glass and cans, newspapers, and mixed refuse for weekly curbside collection. So far, this effort at collecting bottles and cans has been very successful. (See: Hansen, P. and J. Ramsey. Demonstrating Multimaterial Source Separation In Somerville and Marblehead, Massachusetts. Waste Age, 7(2): 26-27,48, February 1976. Reprinted, (Washington), U.S. Environmental Protection Agency, 1976. 4 p.)

Page II-3, paragraph 3 through page II-8: See Number 2, above.

Page II-11: See Nationwide Survey of Resource Recovery Activities. Cite completely

Pages II-18 through II-25: Delete.

μσ1045a

This update sheet was prepared by the Resource Recovery Division, Office of Solid Waste.

An environmental protection publication
in the solid waste management series (SW-125)

Editing and technical content of this report was
the responsibility of the Resource Recovery Division

Single copies of this publication are available
from solid waste management publications distribution unit,
U.S. Environmental Protection Agency, Cincinnati, Ohio 45268

Table of Contents

Introduction	1
Energy Conservation through Source Reduction	9
Energy Recovery from Waste	11
Energy Conservation through Recycling	28
Energy Conservation through Improved Collection	33
Summary	36
References	38
Appendices	39

ENERGY CONSERVATION

THROUGH IMPROVED SOLID WASTE MANAGEMENT

INTRODUCTION

Recent concern about energy supplies and environmental quality has focused attention on how resources are used and on the effects of resource use on the environment. Continued growth in the consumption of materials and the generation of wastes -- with their attendant use and waste of energy -- is neither inevitable nor necessary. Energy could be conserved by improving upon current materials use and waste management practices. This paper presents four opportunities to conserve energy through better solid waste management:

1.	Source Reduction	reducing consumption of products or reusing products, resulting in the use of less energy and materials and in the reduction in waste generation
2.	Energy Recovery	using solid waste as a fuel in place of coal, oil or gas
3.	Recycling	using recycled materials that consume less energy than virgin materials in manufacturing processes
4.	Improved Collection	using waste collection trucks more efficiently, reducing fuel consumption

Considered separately, the "maximum possible" energy savings from each of these four measures is:

	B/DOE* (thousand)	B/YOE** (million)	Btu's*** (trillion)
Source Reduction	115	42	244
Energy Recovery	393	143	832
Recycling	80	30	172
Improved collection	3	1	6

*B/DOE, barrels per day of oil equivalent
**B/YOE, barrels per year of oil equivalent
***Btu's, British thermal units. One trillion = 1×10^{12}

When considering the combination of these four energy conservation measures, the reader should be aware that the total energy benefits from improved solid waste management cannot be determined by adding the potential savings listed above. This is because the four areas are interrelated: energy saved in one area may reduce the potential for savings in another. For example, banning nonrefillable beverage containers (a source reduction measure) will reduce the amount of material available for recycling. Recycling combustible materials like paper will reduce the amount of waste available for energy recovery.

Some of the energy savings are additive. For example, energy recovery can be accompanied by the recycling of inorganic (noncombustible) materials. In fact, energy recovery improves the economics of materials

recycling. This occurs because an energy recovery system can usually be economically viable without materials recovery, although the opposite is not true. In an energy recovery system, the noncombustible recyclable materials are typically separated from the mixed waste (and therefore available for recycling) even if they are not going to be recycled. The additional cost of removing the recyclable materials appears to be less than the additional revenues from the sale of those materials.

In general, the largest quantity of energy is conserved by combining measures despite the reductions in certain categories. The potential energy savings from combining all measures in one possible scenario are:

	B/DOE* (thousand)	B/YOE (million)	Btu's (trillion)
Source Reduction	115	42	244
Energy Recovery	357	131	757
Recycling	46	17	98
Improved Collection	3	1	6
Total	521	191	1,105

*From Scenario 3 on Table 8 in the Summary
Note: See footnotes to Table 8.

Examples of the effects of certain energy conservation measures on other measures will be presented in the Energy Recovery and Recycling sections. An overview of the combined energy savings from

three possible energy conservation scenarios will be presented in the Summary.

To put these four energy conservation opportunities in perspective they should be understood in the context of the flow of materials from acquisition of natural resources, through processing and manufacturing, to product use and waste disposal.

Existing methods of materials use and waste generation have two important consequences. First, a large portion (almost 50 percent) of the Nation's energy supply is consumed by the industrial sector. For example, fuel is consumed by the equipment that removes iron ore from the ground and transports the ore to the steel mill. Then energy is used to melt the ore and process it into steel. Next, energy is required for the equipment that transforms the steel into usable products in the manufacturing process. Finally, energy is consumed in the disposal operation (tractors on a landfill or in a resource recovery system). And all along, energy is consumed in transporting the material or product from each step to the next, including the final transport step: waste collection. Therefore, any reduction in the consumption of materials and products could conserve energy. The section on Source Reduction will discuss this further.

Secondly, conventional disposal methods--landfill or incineration without energy recovery--waste energy. A large portion of the materia discarded into the waste stream are combustible and can be converted

into energy, thereby conserving valuable fossil fuels. The waste stream also contains valuable materials--steel, aluminum, paper, glass--that can be recycled. Generally, although not in all cases, it takes less energy to manufacture a product from recycled materials than from virgin materials when all stages of materials acquisition, processing, manufacturing, and transportation are considered. To get a better appreciation for the opportunities for recovering energy and recycling materials, a closer look at the waste stream would be desirable.

The Waste Stream

EPA estimates that about 125 million tons of municipal wastes were generated from residential and commercial sources in the U.S. in 1971 (3.32 lbs/person/day).[1] Table 1 shows a breakdown of the waste stream, cross-referenced by material and by product. Product source categories are presented in millions (10^6) of tons on an "As Generated" basis. The materials in the waste stream are presented in millions of tons on both an "As Generated" and an "As Disposed"

---

[1]This waste generation rate is lower than the widely quoted 190 million tons/year (5.3 lbs/capital/day) estimated in the 1968 National Survey of Community Solid Waste Practices. The National Survey was based on a sample of collected tonnage estimates (rather than systematic measurements) that were extrapolated to a national scale. These more recent estimates are primarily based on national material production and product marketing data. It is the judgement of EPA that these new figures are accurate to within approximately 25 percent and the 1968 survey over-estimated the national municipal solid waste stream.

TABLE 1

MUNCIPAL SOLID WASTE GENERATION
BY MATERIAL AND SOURCE, 1971

Kinds of Materials	Product Source Categories							Material Totals			
								"As-Generated" Basis		"As Disposed" Basis	
	Newspapers, books, and magazines	Containers and Packaging	Major household appliances	Furniture and furnishings	Clothing and footware	Food products	Other products	10^6 Tons	Percent	10^6 Tons	Percent
Paper	10.3	20.4	---	tr.	tr.	---	8.4	39.1	31.3	47.3	37.8
Glass	---	11.1	tr.	tr.	---	---	1.0	12.1	9.7	12.5	10.0
Metals	---	6.1	1.9	0.1	tr.	---	3.8	11.9	9.5	12.6	10.1
Ferrous	---	5.4	1.7	tr.	---	---	3.5	10.6	8.5		
Aluminum	---	0.6	0.1	tr.	---	---	0.1	0.8	0.6		
Other nonferrous	---	0.1	0.1	tr.	---	---	0.2	0.4	0.3		
Plastics	tr.	2.5	0.1	0.1	0.2	---	1.3	4.2	3.4	4.7	3.8
Rubber & leather	---	tr.		tr.	0.5	---	2.7	3.3	2.6	3.4	2.7
Textiles	tr.	tr.	---	0.6	0.5	---	0.7	1.8	1.4	2.0	1.6
Wood	---	1.8	---	2.3	tr.	---	0.5	4.6	3.7	4.6	3.7
Food Wastes	---	---	---	---	---	22.0	---	22.0	17.6	17.7	14.2
PRODUCT TOTALS	10.3	41.9	2.1	3.2	1.2	22.0	18.4	99.1	79.3	104.9	83.9
Yard Wastes								24.1	19.3	18.2	14.6
Misc. Inorganics								1.8	1.4	1.9	1.5
TOTAL WASTE								125.0	100.0	125.0	100.0
Percent Product Source Composition	8.2	33.5	1.7	2.6	1.0	17.6	14.7	---	79.3	---	83.9

basis. "As Generated" measures the weight of the material before it is mixed with other wastes. "As Disposed" measures the weight of the material after being mixed in trash cans and collection trucks. The difference between the two is the result of the migration of moisture from the wetter materials (food and yard wastes) to materials that absorb moisture (note the increase in the weight of paper) and to products to whose surface the moisture adheres (such as glass and metals).

The figures in Table 1 include wastes generated in household, commercial and business establishments and institutions (schools, hospitals, etc.) and excludes industrial process wastes, agricultural and animal wastes, abandoned automobiles, ashes, street sweepings, construction and demolition debris, and sewage sludges. The 125 million ton figure includes only those materials discarded into the waste stream and, therefore, excludes certain amounts of newsprint, corrugated and other materials that are already being recycled.

Large quantities of agricultural, forestry and industrial wastes and sewage sludge are generated each year. The amount of energy recoverable from these wastes may be significant; however, these wastes are not included in this analysis because the economic feasibility of recovering energy from them has not been determined.

The amount of products consumed and wastes generated has been growing at a rate estimated at 3 percent per year over the last decade. The population increased about 13 percent during the 1960's.

Although the population is growing slower now than in earlier years, the generation of wastes continues to increase.

These trends indicate a projected 3 to 4 percent annual increase in the amount of wastes generated in the years ahead. This means that more wastes will be available for energy recovery and materials recovery. More importantly, however, it means that the demand on supplies of natural resources will be greater and that more energy will be required to convert those resources into usable products. Thus, the need to conserve energy and to consume fewer products should become more apparent.

ENERGY CONSERVATION THROUGH SOURCE REDUCTION

Source reduction is defined as the reduction in the generation of solid waste through a reduction in the consumption of materials and products. There are four general approaches to achieve source reduction:

1. Product reuse (e.g., returnable bottles)
2. Reduce resource intensiveness (e.g., smaller autos)
3. Increased product lifetime (e.g., longer lasting household appliances)
4. Decreased product consumption (e.g., reduced packaging consumption)

Table 1 indicates some of the broad product categories in the waste stream that could be impacted by source reduction measures.

Almost invariably, any source reduction action will result in the conservation of energy. Although the energy conservation impacts of most of the many possible source reduction actions have not been quantified, an estimate was made of the potential energy savings resulting from a reduction in one product category, packaging, to put the energy conservation potential of source reduction in perspective. If per capita packaging consumption in 1972 were reduced to the levels that existed in 1958, over 560 trillion Btu's could have been saved in 1972, the equivalent of 267,000 B/DOE (Appendix I).

Another source reduction measure, affecting a portion of the packaging category, is the substitution of refillable (returnable) beverage containers for nonrefillable (one-way) containers. Using a refillable container saves at least half of the energy required to use a nonrefillable bottle or can. If all beverages were shipped in refillable bottles in 1972 (and each bottle were used 10 times and returned to the bottler in "piggy back" fashion on the return trips of the consumer's automobile and the distributor's truck), about 244 trillion Btu's or 115,000 B/DOE could have been conserved.

It is significant to note that per capita consumption of materials has grown considerably in recent years. Consumption of packaging materials, for example, has grown at a rate of 2.8 percent per person per year for the last 13 years. Based upon projected growth rates, the energy that could be saved by returning to 1958 per capita packaging consumption rates will be twice as large (1,174 trillion Btu's, or 555,000 B/DOE) in 1980 as in 1972.

The consumption of beverage containers has also grown, and continues to grow, faster than population growth and the consumption of beverages. For example, while the consumption of beer and soft drinks rose 29 percent between 1959 and 1969, the consumption of beer and soft drink containers rose 164 percent. Based upon projected trends continuing toward use of nonrefillable beverage containers, if all consumers in 1980 use refillable bottles (and these bottles are used 10 times), about 421 trillion Btu's (70 percent more than the potential savings estimated for 1972) or about 198,000 B/DOE could be saved.

ENERGY RECOVERY FROM WASTE

Theoretical Energy Potential

About 70 to 80 percent of residential and commercial wastes is combustible with an energy content of about 9 million Btu's per ton. Theoretically, if all solid waste in the U.S. had been converted into energy in 1971, about 1.1 quadrillion (1.1×10^{15}) Btu's per year would have been generated. This is the equivalent of over 522,000 B/DOE, or 190 million B/YOE. The growth in population and per capita waste generation would cause these figures to increase to 1,440 trillion Btu's per year by 1980, or about 680,000 B/DOE or 248 million B/YOE. These and other findings are summarized on Table 2. (Appendix II)

Available Energy Potential

Not all waste is available for energy recovery. Energy recovery systems require large quantities (at least 200 to 250 tons per day) of waste delivered for processing at one site in order to achieve economies of scale. For this reason, energy recovery appears feasible only in more densely populated areas, such as Standard Metropolitan Statistical Areas (SMSA's). If energy recovery had been practiced in all SMSA's in 1971, over 832 trillion (832×10^{12}) Btu's would have been recovered. This is equal to over 393,000 B/DOE, or 143 million B/YOE. By 1980, the energy potentially recoverable from the SMSA waste stream is projected to be about 1,085 trillion Btu's per year, the equivalent of over 512,000 B/DOE, or 187 million B/YOE.

TABLE 2

ENERGY POTENTIALLY RECOVERABLE FROM WASTE

	1971			1980		
	Btu's* (trillion)	B/DOE** (thousand)	B/YOE*** (million)	Btu's (trillion)	B/DOE (thousand)	B/YOE (million)
Theoretical	1,106	522	191	1,440	680	248
Available	832	393	143	1,085	512	187
Projected Implementations	-	-	-	85	40	15
Potential Candidates	-	-	-	558	263	96

*Btu: British Thermal Unit

**B/DOE: Barrels per day of oil equivalent. (Assuming 5.8 million Btu's per barrel of oil and 365 days per year.)

***B/YOE: Barrels per year of oil equivalent.

Using solid waste as an energy source offers several distinct benefits:

1. Replaces the use of fossil fuels.
2. Produces low sulfur oxide emissions because solid waste has a low sulfur content.
3. Reduces the amount of land needed for disposal sites.
4. Is a readily available, growing--rather than depleting --domestic source of energy.

Projected Implementations of Energy Recovery Systems

At the present time, energy is being recovered from post-consumer solid waste in only one location in the U.S.: in St. Louis, Missouri at an EPA-supported demonstration plant operated by the City of St. Louis and the Union Electric Company.

Interest in energy recovery is increasing across the country. Several more systems (including another Federally supported demonstration plant) will be operating before the end of 1975. About 40 additional communities are seriously considering the recovery of energy from waste.

Based on energy recovery projects existing or planned at the present time, it is projected that by 1980 almost 30 cities and counties around the country should be operating the equivalent of about thirty-six 1,000 ton-per-day plants, recovering an estimated 85 trillion Btu's per year, or 40,000 B/DOE, or 15 million B/YOE.

A list of communities where energy recovery systems are underway or planned is included in Table 3. This list represents those communities that have already taken definite steps (by conducting a feasibility study, by vote of the county legislative body, or by some similar step) towards implementation of an energy recovery system. However, there are many other cities that are potential candidates for energy recovery systems.

TABLE 3

PROJECTED IMPLEMENTATIONS OF ENERGY RECOVERY SYSTEMS BY 1980

State	City	Tons of Solid Waste Per Day (1980)
California	San Diego	200
Connecticut	Bridgeport	1,200
District of Columbia	Washington	1,000
Illinois	Chicago	2,000
	Chicago area, outside city	1,000
Iowa	Ames	200
Maryland	Baltimore	1,000
	Montgomery County	1,200
Massachusetts	Braintree	240
	East Bridgewater (near Brockton)	1,200
	Lawrence	1,000
	Saugus (near Boston)	1,200
Missouri	St. Louis	8,000
New Jersey	Essex County (Newark area)	1,000
	Hackensack Meadowlands	2,000
	Union County (Elizabeth) or Middlesex County (New Brunswick)	1,000
New York	Albany	500
	Hempstead, L.I.	1,000
	Monroe County (Rochester)	500
	New York City	2,000
	Westchester County (White Plains)	1,500
Ohio	Akron	1,000
	Cleveland	500

TABLE 3, Continued

State	City	Tons of Solid Waste Per Day
Oregon	Eugene	700
Pennsylvania	Philadelphia	2,400
Puerto Rico	San Juan	1,000
Tennessee	Knoxville	500
	Memphis	500
	Nashville	750
	Total Tons Per Day in 1980	36,290
	Number of equivalent 1000 tons per day plants	36
	Energy recoverable in 1980	85 trillion Btu's per year
		40,000 barrels per day of oil equivalent
		15 million barrels per year of oil equivalent

Potential Candidates: Areas Where Local Conditions Favor Energy Recovery

In some areas, there are certain local conditions that favor the implementation of energy recovery systems. These include:

1. Economics - where disposal costs are high because inexpensive close-by land is not available or because alternative fuel costs are high.

2. Markets - where local market conditions exist to take advantage of available technology. These conditions include a boiler suitable for burning waste or a network for distributing steam for heating downtown buildings.

3. Public Interest - where public officials are likely to select energy recovery over other options because of the popularity among their constituents of energy recovery as an environmental or energy issue.

Using these local conditions as screening criteria, EPA has identified 48 SMSA's as potential candidates for energy recovery. These 48 SMSA's are metropolitan areas that include at least 100 to 150 separate county or city governmental units. A list of these SMSA's is included in Table 4. These are the areas where energy recovery could be feasible by 1980, while the previous list (Table 3) indicated recovery systems that are expected to be implemented. The distinction between the two lists is the difference between actual implementations and opportunities for implementation. The energy recoverable from all the residential and commercial waste in these 48 areas in 1980 would be equal to over 263,000 B/DOE, or 96 million B/YOE.

TABLE 4

POTENTIAL CANDIDATE AREAS (SMSA's)
FOR ENERGY RECOVERY IN 1974
with potential energy recoverable projected to 1980

Note: Recoverable energy is a function of waste generation, which is a function of population

	Standard Metropolitan Statistical Areas	Population 1970 (thousands)
1.	New York, New York	11,572
2.	Chicago, Illinois	6,979
3.	Philadelphia, Pennsylvania	4,818
4.	Detroit, Michigan	4,200
5.	Washington, D.C. - Md. - Va.	2,861
6.	Boston, Massachusetts	2,754
7.	Pittsburgh, Pennsylvania	2,401
8.	St. Louis, Missouri	2,363
9.	Baltimore, Maryland	2,071
10.	Cleveland, Ohio	2,064
11.	Newark, New Jersey	1,857
12.	Minneapolis - St. Paul, Minnesota	1,814
13.	Milwaukee, Wisconsin	1,404
14.	Atlanta, Georgia	1,390
15.	Cincinnati, Ohio	1,385
16.	Patterson, New Jersey	1,359
17.	San Diego, California	1,358
18.	Buffalo, New York	1,349
19.	Miami, Florida	1,268
20.	Denver, Colorado	1,228
21.	Portland, Oregon	1,009
22.	Columbus, Ohio	916
23.	Providence, Rhode Island	911
24.	Rochester, New York	883
25.	San Antonio, Texas	864
26.	Louisville, Kentucky	827
27.	Memphis, Tennessee	770
28.	Albany, New York	722
29.	Toledo, Ohio	693
30.	Akron, Ohio	679
31.	Hartford, Connecticut	664
32.	Gary, Indiana	633
33.	Jersey City, New Jersey	609
34.	Nashville, Tennessee	541
35.	Jacksonville, Florida	529
36.	Wilmington, Delaware	499
37.	Knoxville, Tennessee	400

TABLE 4, Continued

38.	Bridgeport, Connecticut	389
39.	New Haven, Connecticut	356
40.	Peoria, Illinois	342
41.	Little Rock, Arkansas	323
42.	Chattanooga, Tennessee	305
43.	Madison, Wisconsin	290
44.	Rockford, Illinois	272
45.	Lawrence, Massachusetts	232
46.	Charleston, West Virginia	230
47.	Eugene, Oregon	213
48.	Brockton, Massachusetts	190
	Total population, 1970	71,786
	Total population, 1980	78,462
	Waste generation, 1980 (annual)	62.0 million tons
	(daily)	170 thousand tons
	Number of equivalent 1000 TPD plants	170
	Energy recoverable	558 trillion Btu's per year
		263,000 barrels per day of oil equivalent
		96 million barrels per year of oil equivalent

Energy Recovery Products

Solid waste can be used as or converted into any of five individual energy products (Reference 1):

1. Steam
2. Solid fuel
3. Liquid fuel
4. Gaseous fuel
5. Electricity

To aid in conceptualizing the state of the art of energy recovery, this section presents these five energy products and distinguishes them from one another at the point of sale. This distinction is made because the selection of an energy recovery system will be made primarily on the basis of marketing considerations; that is, the system will be designed so that its products will be accepted by the potential customers in the market.

Two of the five products--steam and electricity--are end-products. Steam is also an intermediate product when it is used to generate electricity. Solid, liquid and gaseous fuels are raw materials that can be burned to produce either end-product, steam or electricity. These fuels can come either from fossil resources (coal, oil or gas) or from solid waste (shredded/classified waste-fuel, or pyrolysis oil

or gas). Therefore, solid waste can be a source of energy, whether it is sold as steam, fuel or electricity.

Steam

By burning solid waste in a water wall incinerator, steam can be generated for use in (1) heating and cooling buildings (district heating and cooling) and (2) industrial manufacturing.

Technically, steam recovery is the best-developed method for recovering the energy value in solid waste. But marketing steam is often a difficult task because (1) steam is not storable and (2) can be transported only over very short distances. Nevertheless, many cities have steam distribution networks already established.

The Nashville (Tennessee) Thermal Transfer Corporation, a private non-profit corporation, will soon begin full scale operation of a facility to produce steam and chilled water for heating and cooling downtown buildings. The energy will be provided by a water wall incinerator fueled entirely (except for emergency situations) by solid waste. Steam and chilled water will be sold at prices that result in substantial savings to customers. At the same time, the revenues from these sales will pay for all capital and operating costs, including underground distribution lines. Moreover, the City will be able to dump its waste at the plant at no charge. (The City is responsible for disposing of the residue.)

Rather than build a new water wall incinerator to produce and sell steam, it may be more economical to sell the waste as a fuel to supplement the fossil fuels used in existing steam generating boilers.

Solid Fuel

Solid waste can be sold in solid form as a substitute for conventional fossil fuels in existing or newly designed combustion units. The major markets for solid waste fuel are (1) utility boilers (2) industrial steam and steam-electric boilers, and (3) district heating and cooling facilities (i.e., heating downtown buildings).

The largest and most readily available boilers are electric utility boilers. Because most of these boilers are suspension fired (the fuel burns in mid-air in a residence time of one or two seconds), the pieces of solid waste fuel must be reduced in size (by shredding, milling or pulping) so that they can be burned in the boilers' short residence time. Burning prepared solid waste as a supplement to coal in an existing utility boiler has been demonstrated in St. Louis, Missouri. This system is described in Energy Recovery from Waste. (Reference 2)

The prerequisite for this application is that the boilers must be capable of handling ash--both bottom ash and fly ash. All boilers designed to burn coal have ash handling equipment. Although many coal-burning boilers were subsequently retrofitted to burn oil or gas, the ash handling equipment is still operable in most cases. Where the Boilers Are: A Survey of Electric Utility Boilers with Potential Capacity for Burning Solid Waste as a Fuel (Reference 3) describes the location, design characteristics and the refuse-burning capacity of most of the utility boilers in the U.S. capable of burning solid waste.

Oil and Gas through Pyrolysis

To enable solid waste to be used in boilers that do not have ash-handling capabilities, the solid waste can be converted into a combustible liquid or gas using a process known as pyrolysis.

Pyrolysis is the thermal degradation of organic substances in an oxygen deficient atmosphere. The concept is under development by nearly a dozen different private and public organizations. The primary motivation is to develop a system wherein solid waste can be converted into a storable, transportable fuel--either liquid or gas. Once this is done, many of the constraints that limit the marketability of solid waste as a fuel are minimized.

At this time, several pyrolysis systems have been demonstrated at the pilot plant level, 4 to 150 tons per day, but no full-scale systems are operational. Several plants will be operational within the next year or two. Monsanto Enviro-Chem Systems, Inc. is building a 1,000 ton per day gas pyrolysis plant in Baltimore, Maryland with EPA support. Union Carbide Corporation is building a 200 ton per day gas pyrolysis plant in South Charleston, West Virginia. And Garrett Research & Development Corporation is building a 200 ton per day oil pyrolysis plant in San Diego County, California, also with EPA support. By 1980, sufficient experience should be gained to make this a viable option for widespread implementation.

Gas: Methane Recovered from Landfills

Gases are produced in land disposal sites as a result of the microbiological decomposition of the organic matter (such as food, paper and yard wastes) placed in the landfill. One of these gases is methane, a combustible gas that is the main component of natural gas. These gases can be recovered and used either as a fuel in engines designed to run on methane or, after treatment to remove impurities, as a substitute for natural gas in conventional commercial pipelines.

At the present time, methane is being recovered at only one site: a pilot plant operated by the Los Angeles Power and Water Company on the City of Los Angeles' Sheldon-Arleta Landfill. Plans are already underway to expand this facility and another.

Methane recovery utilizes available technology, but there are still several unknowns. The most important unknown is the length of time that landfills will produce methane. Nevertheless, the economics of this energy recovery option are becoming more favorable as the value of natural gas increases.

Electricity

Instead of selling prepared waste as a solid fuel, solid waste can be converted into electricity; and then the electricity can be sold. There are two ways of doing this: steam-electric boilers and gas turbines. These two options have significant shortcomings at the present time.

The economics of steam-electric boilers are most favorable when they are large enough to have economies of scale and when the heating value per unit of volume of the fuel is high (and thus less boiler area is required for combustion). Steam-electric boilers designed to burn only solid waste appear to be less economical than boilers designed to burn waste in combination with fossil fuels because (1) the heating value of waste fuel per unit of boiler combustion area is lower than fossil fuels and (2) the amount of waste that can be delivered economically to one site is far lower than fossil fuels. Gas turbines using solid waste as an energy source are encountering technical difficulties. Therefore, at the present time, selling electricity produced from waste appears to be an option that is less advanced than those discussed above.

Effect of Paper Recycling on Energy Recovery

Waste paper can be recycled as a fiber source; or it can be converted to energy. (Recycled paper can be converted to energy at a later time.) At the time of disposal, these options--recycling or energy recovery--are mutually exclusive. Obviously, the effect of removing paper from the waste stream is important in the management and design of an energy recovery system.

Paper can be removed from the waste stream in several ways:

1. Source separation:	separating paper at the home or factory for recycling before it is mixed with other wastes during the collection process
2. Hand picking:	removal of bundled paper from the mixed waste
3. Mechanical separation:	removal of paper fiber by mechanically processing the mixed waste stream

Only certain types of paper products can be segregated at the source and collected economically for recovery. (Reference 4) These grades of paper, which account for about 47 percent of all the paper in the waste stream are:

1. Newspapers from residential sources,
2. Corrugated from commercial and industrial sources, and
3. Mixed office papers

It is estimated that 40 to 60 percent [2] of this paper could realistically be recovered. Expressed as a percentage of all the paper in the waste stream, this represents a recovery rate of about 27 percent.

---

[2]Available paper excludes the paper presently being recycled; recovery percentages would be higher if presently recycled paper were included.

Table 5 shows the effect on the heating (energy) value of the waste stream at various rates of recovery through source separation of the available paper grades (newsprint, corrugated and mixed office papers).

TABLE 5

EFFECT OF SOURCE SEPARATION

of Newspaper, Corrugated and Mixed office papers

Recovery Rate (percent of all paper)	Reduction in Heating Value of the Waste Stream (percent)
0%	0%
15	4
27	7
35	9

If energy recovery had been practiced in all SMSA's in 1972 simultaneously with a 35 percent rate of source separation and recycling of paper, the amount of energy recoverable from waste would have been reduced about 9 percent, from 393,000 B/DOE to 357,000 B/DOE. The energy consequences of producing paper from recycled fiber will be discussed in the following section.

ENERGY CONSERVATION THROUGH RECYCLING

Recycling generally conserves energy: when two production systems are compared--one using virgin materials and the other using recycled (secondary) materials--the system using recycled materials most often consumes less energy when all stages of materials acquisition, processing and transportation are included.

The technical feasibility of recovering materials from the municipal waste stream has been demonstrated. Had currently-known technology been applied in 1972 to residential and commercial solid wastes in metropolitan areas, almost 14 million tons of steel, aluminum and glass could potentially have been recovered and substituted for their virgin material counterparts.

Such a substitution, based on preliminary estimates, (Appendix III) would have yielded a national primary energy saving of about 172 trillion Btu's per year in 1972, or the equivalent of 80,000 B/DOE. Moreover, the potential energy savings from recycling in the future is expected to grow in proportion to projected increases in the consumption of recyclable materials. (Table 6)

In the area of paper recycling, using recycled fiber in the paper and paperboard production systems appears to require less energy than using virgin woodpulp. However, no estimates of the potential energy savings have been presented in this analysis for three reasons. First, independently developed estimates on the energy effects of paper

TABLE 6

NATIONAL ENERGY SAVINGS FROM MAXIMUM POSSIBLE RECYCLING OF ALUMINUM, FERROUS, AND GLASS FRACTIONS OF POST-CONSUMER SOLID WASTE [TRILLIONS OF BTU'S]*

Materials**	1972	1975	1980	1985	1990
Aluminum [46-56%]	82	115	164	212	274
Ferrous [63-67%]	81	87	95	107	116
Glass [50-52%]	8	13	15	16	16
Total Energy	172	215	274	335	406

*Energy savings are based on "total system" analyses which include primary energy required for raw material acquisition and electricity input as well as for principal refining processes.

**Figures in brackets indicate percentages of the individual material in nation-wide solid waste assumed to be recoverable from a "maximum possible" recovery effort. Lower percentages are for earlier years, higher percentages for later years when larger proportions of popula- is expected to reside in SMSA's and when extraction efficiency expected to rise. Recovery quantities based on residential and commercial solid waste only.

recycling differ materially in certain significant quantitative details. Until these estimates are systematically and thoroughly compared and reconciled, meaningful data are not available. Secondly, the more energy intensive virgin pulping operation typically derive at least part of their energy requirements from bark and other wood wastes rather than from fossil fuel sources. In some cases, by-product energy derived from spent pulping liquors is sufficient to supply all of or more than the pulping energy requirements. Thirdly, a satisfactory definition of the "maximum possible" paper recycling scenario has not been developed, mainly because there are a great many variables on both the supply and demand sides of the waste paper utilization picture. Unlike the other three waste materials previously estimated (aluminum, ferrous, and glass) the potential incremental supply of post-consumer waste fiber supply would be not only a very large fraction of total national fiber consumption, it could also be directed (from a technical standpoint) into an almost infinite variety of product use patterns.

Effect of Source Reduction on Recycling

It was mentioned earlier that implementation of one energy conservation measure may reduce the benefits from another. One example of this is the effect of source reduction on the potential energy savings from recycling. Because source reduction will decrease the amount of materials available for recycling, the potential energy savings resulting from recycling will also be reduced by source reduction. Therefore, the energy savings from

source reduction of recyclable materials and the energy savings from recycling are not additive.

However, based on estimates involving beverage containers, the energy savings from source reduction appear to be greater than the energy savings from recycling. For example, as was noted earlier, if all consumers had used only refillable bottles in 1972, about 244 trillion Btu's or 115,000 B/DOE could have been saved because of source reduction.

But this source reduction action would have removed about 6.2 million tons of material from the waste stream that could have been recycled. This assumes that steel and aluminum beverage cans would not have been used because they cannot be refilled; it also assumes that refillable bottles would make 10 "trips" (the original and 9 successive fillings). The effect on materials used, in millions of tons, would have been as follows:

	Beverage Container Materials Used in 1972	Beverage Container Materials Used in an All-returnable System	Beverage Container Materials Removed from the Waste Stream
Aluminum	.5	-	.5
Steel	2.0	-	2.0
Glass	6.2	2.5	3.7
	8.7	2.5	6.2

If these 6.2 million tons of materials had not been available for recycling in 1972 because of an all-refillable bottle program, the effect on Table 6 above would have been as follows:

Materials	Energy Savings from Maximum Possible Recycling 1972 (trillion Btu's)	Energy Savings "Lost" because of use of Refillable Bottles-1972 (trillion Btu's)	Energy Savings from Recycling when only Refillable Bottles are used 1972 (trillion Btu's)
Aluminum	82	55	27
Ferrous	81	16	65
Glass	8	2	6
	172	73	98

Thus, if an all-refillable bottle program were in effect in 1972, 250 trillion Btu's could have been saved because of source reduction, but the energy savings from recycling would have been reduced by 73 trillion Btu's. In terms of barrels per day of oil equivalent, 115,000 B/DOE could be saved because of this source reduction measure, while the potential savings from recycling would be reduced by 34,000 B/DOE (from 80,000 B/DOE to 46,000 B/DOE).

ENERGY CONSERVATION THROUGH IMPROVED COLLECTION

The preceding sections focused on the energy conservation impacts associated with producing and recycling the waste materials themselves. An additional energy conservation opportunity is associated with the collection of solid waste. Solid waste collection is highly dependent on fuel, but there are several short and long range steps which can be taken to conserve energy (Reference 5).

Background

Solid waste collection and land disposal consume 287 million gallons of gasoline and 326 million gallons of diesel fuel per year. Of these figures, collection operations consume approximately all of the gasoline and half of the diesel fuel. Almost three-quarters of the fuel used for solid waste collection is consumed in residential collection.

Use of diesel fuel for solid waste collection and disposal is about 3.6 percent of all highway use of diesel fuel. Use of gasoline for solid waste collection is about 1.6 percent of all truck use of gasoline.

Energy Conservation Measures

The following short range steps could be taken to reduce energy requirements for residential solid waste collection:

1. If communities that presently collect solid waste twice a week were to collect only once a week, those communities could save 29 percent of the fuel used for collection.
2. Communities with separate collection of food waste could essentially halve their fuel requirements by collecting all wastes at once. However, separate collection of newspaper and other materials for resource recovery should be encouraged because the energy saved in the recycling process typically offsets the additional fuel required for collection.
3. A savings of 5 percent could be made in those communities which have poor routing.
4. Other short term changes include:
   a. Improved storage practices
   b. Conversion from backyard to curbside pick-up
   c. Minimizing separate pick-ups for bulky items
   d. Placing waste in clusters or on one side of the street
   e. Reducing street sweeping operations

Long term actions include use of transfer stations where warranted, use of better and properly sized collection equipment, elimination of situations where several private collectors operate on the same street, and location of disposal sites nearer to population centers.

Impact

On a national basis, it is estimated that 18.2 million gallons of diesel fuel and 39.1 million gallons of gasoline per year would have been saved by changing from twice-a-week to once-a-week collections (excluding inner-city areas) and by using better routing patterns for collection. This is based on levels of service and equipment utilization in the 1972-1973 time period. This savings is the equivalent of 3,000 B/DOE.

SUMMARY

The energy conservation measures described above could be combined in a variety of ways. Table 8 presents the "maximum feasible" energy conservation benefits from three sample scenarios. Note that energy recovery and recycling of noncombustible materials are compatible. Note also in Scenario 2 that, when paper is recycled, the overall fossil fuel conservation potential is reduced; however, there are resource conservation and other environmental impacts associated with recycling paper that may offset a reduction, if any, in potential energy savings. And note that the combination of source reduction and recycling (Scenario 3) offers a larger potential energy savings than either option by itself.

Of the three scenarios depicted in Table 8, Scenario 3 offers the greatest potential benefits, 521,000 B/DOE. This is a significant quantity of energy. By comparison, 521,000 B/DOE is equal to:

7 percent of all the fuel consumed by utilities in 1970 (7.1 million B/DOE

14 percent of all the coal consumed by utilities in 1970 (3.7 million B/DOE)

35 percent of the oil projected to be delivered through the Alaskan Pipe Line (1.5 million B/DOE)

52 percent of the crude oil imported directly from the Middle East in Sept., 1973 (1.0 million B/DOE)

1.5 percent of all energy consumed in the U.S. in 1970 (32.5 million B/DOE)

Table 8

Combined Energy Savings from Three "Maximum Possible" Energy Conservation Scenarios for 1972 (thousand barrels per day of oil equivalent)

	Scenario 1	Scenario 2	Scenario 3
	Energy Recovery Recycling and Improved Collection	Energy Recovery Recycling, Improved Collection and Source Separation	Energy Recovery, Paper and Materials Recycling, Improved Collection and Source Reduction
Energy Recovery	393	357[1]	357[1]
Recycling[2]	80	80	46
Improved Collection	3	3	3
Source Separation[3]	-	N.A.	N.A.
Source Reduction[4]	-	-	115
Total	476	440	521

[1]Energy content of wastes reduced 9 percent by source separation. See note 3.

[2]Recycling of noncombustible materials: aluminum, glass and steel.

[3]Source separation and recycling of newsprint, corrugated and mixed office waste papers at a recovery rate of 35 percent of the paper in the waste stream.

[4]Source reduction refers to the beverage container example described above: it assumes that all consumers used refillable bottles and that each bottle made 10 trips.

N.A. - Data on the energy savings from recycling paper are not available. See page 28.

REFERENCES

1. Levy, S. J. Energy recovery markets and technology. (In preparation.)

2. Lowe, R. A. Energy recovery from waste; solid waste as supplementary fuel in power plant boilers. Environmental Protection Publication SW-36d.ii. Washington, U.S. Government Printing Office, 1973. 24 p.

3. Gordian Associates, Inc. Where the boilers are; a survey of electric utility boilers with potential capacity for burning solid waste as a fuel. (In preparation.)

4. Holloway, J. R. The effect of removing paper on the fuel value of solid waste. (In preparation.)

5. Shuster, K. A. Analysis of fuel consumption for solid waste management. (In preparation.)

APPENDICES

I National Energy Savings from Source Reduction--Packaging: An Estimate of Possible Impact, by Michael Loube

II Methodology for Determining the Amount of Energy Potentially Recoverable from Waste, by Robert A. Lowe

III National Energy Savings from Materials Recycling: Some "Maximum Possible" Estimates for Ferrous Metals, Aluminum and Glass, by Frank A. Smith

APPENDIX I

NATIONAL ENERGY SAVINGS FROM SOURCE REDUCTION - PACKAGING: AN ESTIMATE OF POSSIBLE IMPACT

by Michael Loube

Introduction

Source reduction is defined as the reduction in consumption of materials and products which also results in a reduction in the generation of wastes. The source reduction concept has grown out of the thesis that solid waste is an effluent theoretically easier to reduce than dispose. Almost by definition most source reduction actions will result in energy savings.

There are four major technical approaches that can be used to achieve source reduction. They are: 1) reuse of products, 2) reduced resource intensity of products, 3) increased lifetime of products, and 4) decreased consumption of products. The energy savings in the packaging sector described in this paper concern two of these approaches. First, there is an analysis of the energy savings arising from the reuse of the beverage (beer and soft drink) container portion of packaging materials. Secondly there is an analysis of the energy savings achieved if the consumption of all packaging materials (other than beverage containers) could be reduced.

Findings

1. Reuse of Beverage Containers

A source reduction program tailored toward the reuse of beer and soft drink containers (Tables 1-2) will produce a substantial reduction in total energy required for the consumption of beverages. A shift from the current mix of one-way and refillable beverage containers to a system of all refillable containers (the average container being used ten times) would have saved in 1972 a total of 244 trillion Btu's. This potential energy savings is equivalent to about 115,000 barrels of oil, or slightly more than .3% of the nation's total primary energy (fossil fuels plus hydroelectric plus nuclear). By 1980, given the anticipated growth in beverage consumption and shifts between container types, the annual savings that would be generated from a switch to an all refillable system would have increased to approximately 421 trillion Btu's (about 200,000 barrels of oil per day).

2. Reduced Consumption of Packaging (Excluding Beverage Containers)

The energy savings achievable from a source reduction measure that would reduce the consumption of packaging (other than beverage containers) were also estimated (Table 3). Since packaging must protect the product an attempt was made to set as a maximum reduction only the removal of "excess" packaging. This was estimated by identifying the maximum reduction possible as equivalent to 1958 packaging consumption (i.e., the percentage of each material used in packaging in 1958 was assumed to remain constant). Economic growth and increased product consumption since 1958 was then estimated (equal to the increase in non-durable goods purchased) and total packaging consumption was increased to derive a goal for reduced packaging.

The potential energy savings from reduced packaging (excluding beverage containers) would have been, in 1971, 322 trillion Btu's. This savings is equivalent to about 150,000 barrels of oil per day or about .5% of the nation's total primary energy. By 1980, the annual savings that would be generated by decreased packaging consumption would have increased to 753 trillion Btu's (about 356,000 barrels of oil per day).

3. Energy Savings, all packaging materials

These two source reduction measures (reuse of beverage containers, and reduced packaging consumption) are additive (Table 4). Therefore the total energy savings potentially available in the packaging area are:

1) In 1971, 566 trillion Btu's (equivalent to 267,000 barrels of oil per day, or 18% of total primary energy)

2) In 1980, 1174 trillion Btu's (equivalent to 555,000 barrels of oil per day, or 1.7% of present total primary energy demand)

4. Alternative Energy Saving Mechanisms

While source reduction measures designed to reduce or reuse packaging materials provide substantial energy savings, they do impact other potential resource recovery mechanisms. The potential impact on three resource recovery techniques is discussed

below. Impacts are identified for: 1) Separate Collection, 2) Materials Recovery Systems, and 3) Energy Recovery Systems.

A. Separate Collection - Most separate collection activity currently centers on newspapers being segragated by the householder. Source reduction of packaging materials would have no impact on this activity.

A few cities have tried (mostly unsuccessfully) to collect bottles and cans separately. Reuse of beverage containers would probably eliminate the need and potential economic viability of this activity.

Separate collection of corrugated boxes (a packaging material) is practiced (and currently increasing) by some commercial establishments. Since source reduction would probably be accomplished by changing the design of this packaging material in such a way as to use less material or to be reusable, or both, source reduction and separate collection of corrugated packaging could be complementary activities. Both are aimed toward reducing the ultimate waste disposal of packaging materials.

B. Materials Recovery Systems - Few municipal materials recovery systems are currently in existence, but numerous cities are examining their potential (either by themselves or in conjunction with energy recovery systems). If these systems had operated in all metropolitan areas in 1972, the energy saved by recycling the aluminum, glass, and ferrous portions of post-consumer solid waste would have been 172 trillion Btu's (or the equivalent of about 80,000 barrels of oil per day). A source reduction measure designed to reuse beverage containers while saving 244 trillion Btu's would reduce the potential savings from materials recovery (Table 5) by 73 trillion Btu's.

Therefore, material recovery by itself could save 172 trillion Btu's; source reduction of beverage containers by itself could save 244 trillion Btu's. Combined, the two measures would save 343 trillion Btu's as follows:

Energy Savings from Recycling and Source Reduction Combined	
Energy savings from recycling alone	172
less: energy savings "lost" when recycling and source reduction measures are combined	73
Net savings from recycling	99

plus: energy savings from source reduction (refillable bottle program)	244
Total savings from Combined Measures	343

This analysis assumes that the glass remaining in the waste stream with a refillable beverage container system would not be easier to recover for recycling than it is now. This would probably not be true since most glass bottles (even though not refillable because of cracks or chips) would be returned to the supermarket or bottler. The glass bottle waste stream would no doubt be substantially segregated from the general waste stream and therefore easier to recover.

However the effect on energy savings would be small. An additional 0.7 trillion Btu's would be saved (assuming glass recovery efficiency would increase from 50% for normal municipal recovery to 70% for recovery from a segregated glass bottle waste stream).

C. Energy Recovery Systems - Few municipal energy recovery systems are currently in existence, but numerous cities are examining their potential. If these systems had operated in all metropolitan areas in 1972, the energy available for use would have been about 832 trillion Btu's.

Source reduction of packaging materials would remove some of the organic (combustible) materials from the waste stream. This would result in a reduction in the energy available to energy recovery systems in the amount of 82.4 trillion Btu's (Table 6). Energy recovery by itself could save 832 trillion Btu's (see Table 2 in the text); removing combustible materials by source reduction would reduce the energy recovery potential by 82 trillion Btu's to 750 trillion Btu's. However, this 750 trillion Btu savings would be added to the 322 trillion Btu saving attributable to source reduction, for a combined savings of 1,072 trillion Btu's.

5. Net Source Reduction Savings

The total potential energy savings from source reduction of packaging materials including beverage containers would amount to about 566 trillion Btu's in 1972. Various combinations of source reduction approaches, materials recovery and energy recovery systems would provide increased energy savings (Table 7). If all three systems were in existence in 1972, the energy saved would have amounted to 1,415 trillion Btu's.

TABLE 1

Energy Savings of Source Reduction Program-
Reusable Beer and Soft Drink Containers

(1972)

Container Type	Beverage Delivered (Million Oz.)[1]		Energy Required Per Million Oz. (million Btu's)[2]	Energy Consumed (trillion Btu's)		Energy Saving of All Returnable System (trillion Btu's)
	Present System	All Returnable System		Present System	All Returnable System	
Returnable Glass Bottle	293,554	1,007,654	184	54	186	(132)
One Way Glass Bottle	260,989	-	550	144	-	144
Aluminum Can	104,336	-	747	78	-	78
Bi-Metal (Steel) Can	348,775	-	443	154	-	154
Total	1,007,654	1,007,654		430	186	244

1. Midwest Research Institute, Draft Report, Base Line Forecasts of Resource Recovery.

2. Midwest Research Institute, Draft Report, Profile Analysis of Nine Beverage Container Alternatives.

TABLE 2

Energy Savings of Source Reduction Program-
Reusable Beer and Soft Drink Containers

(1980)

Container Type	Beverage Delivered (Million Oz.)[1]		Energy Required Per Million Oz. (million Btu's)	Energy Consumed (trillion Btu's)		Energy Saving of All Returnable System (trillion Btu's)
	Projected System	All Returnable System		Projected System	All Returnable System	
Returnable Glass Bottle	295,673	1,406,980	184	54	259	(205)
One Way Glass Bottle	385,253	-	550	212	-	212
Aluminum Can	301,998	-	747	226	-	226
Bi-Metal (Steel) Can	424,056	-	443	188	-	188
Total	1,406,980	1,406,980		680	259	421

1. Midwest Research Institute, Draft Report, Base Line Forecasts of Resource Recovery.

2. Midwest Research Institute, Draft Report, Profile Analysis of Nine Beverage Container Alternatives.

TABLE 3

Energy Savings of Source Reduction Program-
Decreased Packaging Materials (Excluding Beverage Containers)
(1971 & 1980)

Packaging Material	Total Consumption (thousand tons)[1]			Consumption at 1958 per capita levels (thousand tons)[2]		Potential Material Savings (thousand tons)		Energy Requirement Per ton (thousand Btu's)[3]	Potential Energy Savings (trillion Btu's)	
	1958	1971	1980	1971	1980	1971	1980		1971	1980
Paper	16,552	27,700	39,086	21,137	25,043	6,563	14,043	40,800[4]	267.8	573.0
Glass	5,063	4,900	6,608	6,465	7,660	(1,565)	(1,052)	15,256	(23.9)	(16.0)
Steel	5,340	5,235	6,168	6,819	8,079	(1,584)	(1,911)	29,590	(46.8)	(56.5)
Aluminum	97	212	507	124	147	88	360	196,632	17.3	70.8
Plastics	368	2,900	5,607	470	557	2,430	5,050	36,000	87.5	181.8
Total	27,420	40,947	57,976	35,015	41,486	5,932	16,490		322.5	753.1

(1) Office of Solid Waste Management Programs. Second report to Congress; resource recovery and source reduction. Environmental Protection Agency, Publication SW-122. Washington, U.S. Government Printing Office, 1974. 112 p.

(2) Assumes a return to an equivalent 1958 packaging materials mix (i.e. the percentage of each material used in packaging is assumed to be constant). Economic growth, and increased standards of living, is allowed for by increasing total packaging required by a growth factor (the rate of increase in non-durable goods purchased).

(3) Gordian Associates, Energy Consumption for Six Basic Materials Industries, EPA Draft Report.

(4) Approximately 40% of this energy value is derived from the Btu's contained in the raw material (wood), not from purchased fuels.

TABLE 4

Energy Savings of Source Reduction Program-
Decreased Packaging Consumption

Year	A. Energy Saved From Beverage Container Reusable System (trillion Btu's)	B/DOE[1] (000)	B. Energy Saved From Reduction in All Other Packaging Materials (trillion Btu's)	B/DOE[1] (000)	A. + B. Total Energy Saved All Packaging Materials (trillion Btu's)	B/DOE[1] (000)
1971	244	115	322	152	566	267
1980	421	199	753	356	1174	555

[1]Barrels of oil per day equivalent

TABLE 5

Energy Savings of Source Reduction Program-
Impact of Beverage Container Reuse on Potential
Energy Savings from Materials Recycling

	Materials Used in Beverage Containers 1972 (million tons)[1]	Materials Used if All-refillable System Existed 1972 (million tons)[2]	Material Removed from the Waste Stream (million tons)	Percent Recoverable by Materials Recovery[3]	Material Not Recovered (million tons)	Energy Savings Per Ton Recycled (million Btu's)[4]	Potential Material Recovery Energy Saving "Lost" (trillion Btu's)
Aluminum	.545	-	.545	50	.273	200	55
Steel	2.000	-	2.000	65	1.300	12	16
Glass	6.200	2.500	3.700	50	1.850	1.3	2
Total	8.745	2.500	6.245	-	3.423	-	73[5]

(1) Office of Solid Waste Management Programs. Second report to Congress; resource recovery and source reduction. Environmental Protection Agency, Publication SW-122. Washington, U.S. Government Printing Office, 1974. 112 p.

(2) EPA Analysis based on Midwest Research Institute, Draft Report, Beverage Container Analysis.

(3) Municipal Recovery Systems would receive 72% of total waste stream, recovery efficiency of system is: glass 70%, steel 90%, aluminum 70%.

(4) EPA Analysis.

(5) This energy "loss" of 73 trillion Btu's is smaller than the energy savings (244 trillion Btu's) from reusing beverage containers.

TABLE 6

Energy Savings of Source Reduction Program-
Impact of Reduced Packaging Consumption on Potential
Recovery of Energy from Solid Waste

	Paper	Plastics	Total
Potential Materials Savings from Reduced Packaging Consumption (million tons)[1]	6.6	2.4	9.0
less: Portion not entering the waste stream (million tons)	2.0[2]	.4[3]	2.4
Net amount of materials not available to the total waste stream	4.6	2.0	6.6
less: 28 percent, the waste generated outside of SMSA's[4]	1.3	.6	1.9
Net amount of materials not available to the SMSA waste stream[4]	3.3	1.4	4.7
Btu's per ton of combustible material (million Btu's)[5]	14.8	24.0	
Btu's not available to energy recovery systems (trillion Btu's)	48.8	33.6	82.4[6]

(1) From Table 3.

(2) It was estimated that 30 percent of the paper does not enter the municipal waste stream because of recycling and diversions into other waste streams (water, industrial waste, scrap, etc.).

(3) It was estimated that 15 percent of the plastics does not enter the municipal waste stream for the reasons stated in Note 2, above.

(4) In the estimates of energy recoverable from solid waste, it was assumed that energy recovery is feasible only in SMSA's (Standard Metropolitan Statistical Areas), where economies of scale can be realized.

(5) Assuming paper at 7,400 Btu's per pound and plastic at 12,000 Btu's per pound.

(6) This energy "loss" of 82.4 trillion Btu's is smaller than the energy savings (322.5 trillion Btu's) from reduced packaging consumption.

TABLE 7

Energy Savings of Source Reduction Program-
Four "Maximum Possible" Energy Conservation Scenarios (1972)
(trillion Btu's)

	Scenario 1 Source Reduction and Energy Recovery	Scenario 2 Source Reduction and Materials Recovery	Scenario 3 Energy Recovery and Materials Recovery	Scenario 4 Source Reduction, Energy Recovery, and Materials Recovery
Source Reduction				
A. Reusable Beverage Containers	244	244	-	244
B. Reduced Consumption of All Other Packaging	322	322	-	322
Energy Recovery	750	-	832	750
Materials Recovery	-	99	172	99
Total	1,316	665	1,004	1,415

APPENDIX II

METHODOLOGY FOR DETERMINING THE AMOUNT OF ENERGY POTENTIALLY RECOVERABLE FROM WASTE

by Robert A. Lowe

Theoretical Energy Potential

The amount of energy that could theoretically have been recovered from all the residential and commercial solid waste generated in the U.S. in 1971 is estimated to be 1.1 quadrillion (1.1×10^{15}) Btu's (British Thermal Units) (Table 2 in the text). This is simply a function of (1) the total U.S. population in 1970 (207.0 million); (2) the average amount of residential and commercial solid waste generated (3.32 pounds per person per day, or 125 million tons per year for the entire country); and (3) the energy content of residential and commercial solid waste (4500 Btu per pound).

By 1980, the amount of energy theoretically recoverable from waste is projected to be 1.4 quadrillion Btu's. The increase over 1971 is the result of the projected growth in population and the projected growth in the amount of waste generated per person. The population growth rate reflects the 1970 Series E projections (an increase of 9.3 percent between 1970 and 1980) of the Bureau of Census, U.S. Department of Commerce. The projected per capita waste generation rate for 1980 (an average of 3.91 pounds per person per day) reflects an annual increase of about 1 percent.

All of the basic assumptions--waste generation rate, energy content of waste, population projections and conversion factor to barrels of oil--and why they were selected will be discussed below.

Available Energy Potential

The estimates of the energy potentially recoverable from the residential and commercial wastes generated in Standard Metropolitan Statistical Areas (SMSA's) were made in the same way as those above, with one exception. It was assumed that the average person in an SMSA generates more waste than his rural counterpart. Accordingly, for 1971 a waste generation rate of 3.60 pounds per person per day (4.33 in 1980) was applied to the SMSA population of 140.9 million persons (152.6 million in 1980).

Projected Implementations of Energy Recovery Systems by 1980

This is a projection of energy recovery systems that could be operating by 1980. Unlike the two preceding categories, however, this projection was not made as a function of population; nor was it made solely on the basis of residential and commercial solid waste. Most of the cities and counties included as Projected Implementations (Table 3 in the text) are communities that have taken some definite steps toward implementing an energy recovery system. For example, a few have already begun construction; several others are soliciting proposals from builders and system developers; and in other communities, the legislative body has voted to implement a

system. Several of the communities on the list have not taken such definite steps, but they were included because they have an active planning effort directed towards the energy recovery option.

A brief description of what is taking place in each community listed in Table 3 is included in Exhibit 1. This information was supplied by state and local government officials, representatives of electric utilities and other private companies, and staff of the U.S. Environmental Protection Agency.

It is likely that there will be more energy recovery systems operating by 1980 than Table 3 indicates. This is because there is enough time between the present and 1980 to begin and complete the three to four year implementation process, including planning, design, construction and shakedown.

Potential Candidates: Areas Where Local Conditions Favor Energy Recovery

The list of Potential Candidates (Table 4 in the text) identifies those areas (SMSA's) where certain local conditions in 1974 favor implementation of an energy recovery system by 1980.

As in the first two categories, the energy recoverable from potential candidate areas is a function of population. Being based on the entire population of each area, the projections assume that all the residential and commercial waste generated in each area would be included in energy recovery systems. It may happen that these communities

may chose to put only part--or even none--of their wastes through an energy recovery system. On the other hand, some communities may recover energy from other wastes (such as tires, waste oil and wood chips) that are not included in the residential and commercial waste categories. Nevertheless, all the residential and commercial wastes (and only those wastes) were used as the basis for the projections in order to provide a reasonable "maximum possible" estimate.

The potential candidates were identified using three local conditions as screening criteria:

1. Markets
2. Economics
3. Public Interest

To be considered a Potential Candidate, an area must have, as a minimum, suitable markets to take advantage of existing technology. As a second but critical consideration, an area must have certain economic conditions, such as high disposal costs and high alternative fuel costs. Thirdly, the public must be interested in energy recovery. In certain cases, public interest is so keen that public officials have been encouraged to implement energy recovery even though economic conditions may not warrant it. These criteria were applied in turn to each of the 243 SMSA's ranked by population by the Bureau of Census. (Exhibit 2).

Markets. SMSA's were first screened to determine if suitable markets for waste-based energy are available within a reasonable distance.

The best market approach was assumed to be the use of solid waste as a supplementary fuel in existing electric utility boilers. Use of waste as a fuel for heating downtown areas (district heating) and for industrial boilers is also possible; but data on the location and capacity of these boilers are too limited to screen SMSA's on the basis of these markets. Therefore, each area was examined only for the location of electric utility power plants that are potentially capable of burning solid waste as a fuel. Any utility boiler that was designed to burn coal was considered to be potentially capable of handling solid waste because of its ash handling capability. And if a coal-burning utility boiler were not located in or near an SMSA, that SMSA was excluded from consideration.

Certain exceptions were made. The San Diego SMSA has no ash-handling boilers nearby but was included because it is implementing an EPA-supported oil pyrolysis demonstration plant; San Diego County is planning to utilize pyrolysis on a larger scale if the demonstration is successful. Miami and Jacksonville, Florida, are faced with a critical shortage of disposal space because of a high water table and population density; this primarily economic condition is expected to force these areas to attempt to find markets for waste-based energy even though no suitable utility boilers are available. San Antonio is included because its municipally-owned utility is seriously considering building a new coal-and-waste-burning power plant. Eugene, Oregon (in Lane County) is included because the County is considering retrofitting

its boilers to supplement decreasing supplies of its primary fuel, wood wastes.

Economics. The second screening was made on the basis of three economic criteria:

1. Population size
2. Alternative disposal costs
3. Alternative fuel costs

Energy recovery systems require large quantities of waste (at least 200 to 250 tons per day) delivered for processing at one site in order to achieve economies of scale. To generate 200 tons per day, a population of about 100,000 persons is typically required[1] (assuming each person generates 3.60 pounds per day and the plant operates five days a week). All but 26 SMSA's have a population over 100,000.

Alternative disposal costs are frequently the most important economic factor. The most common influence on disposal costs is the availability of land nearby. Many communities, especially in the cities and suburbs, have land that is undeveloped but not available for disposal because of local resident opposition, high property values or adverse physical conditions (e.g., high water table). These communities must seek disposal sites farther away and, consequently,

---

[1]There will be exceptions to this somewhat arbitrary minimum size requirement. Ames, Iowa, (population 40,000) for example, is about to begin construction on a 200 ton per day energy recovery system.

bear the additional transportation costs.

Most of the SMSA's listed as potential candidates were found to be approaching the limit of present disposal site capacity and having difficulty in obtaining additional capacity. This is a particularly critical problem in the densely populated Northeast. By comparison, cities like San Francisco and Los Angeles appear to have found long term disposal capacity in relatively nearby canyons.

As alternative fuel costs increase, the economics of energy recovery become more favorable because the value of the waste-based energy is usually measured by the value of the fuel that it replaces. High fuel costs, however, have only minor significance in decisions to implement energy recovery because of the small potential impact on the economics of the fuel user, especially the electric utility. Nevertheless, it became apparent that most SMSA's that qualified as Potential Candidates had higher fuel costs than non-candidates. Again, this is especially true in the densely populated Northeast, where the more expensive fuels (low sulfur coal and oil) are required to meet stricter environmental standards.

Public Interest. Public interest in energy recovery has become an increasingly important influence on the public decision-making process, especially as public officials have become more sensitive to environmental and energy issues. In communities where public officials are considering energy recovery as an option based on their perception of its economic,

environmental and political benefits, these public officials appear to have, as a minimum, the tacit support of their constituents. In some communities where conditions do not readily favor energy recovery (for example, sufficient land disposal capacity is available), the public's interest in environmental issues is so strong that public officials are planning to implement (or are now implementing) energy recovery systems anyway. This strong public support for environemental issues is evident in several states, including Colorado, Connecticut and Oregon.

These three screening criteria were applied to each SMSA. In evaluating each SMSA as a possible Potential Candidate, certain factors were more important than others. Exhibit 3 indicates the criteria that determined the judgment about each SMSA.

Waste Generation Rates

The following per capita waste generation rates were used in the calculations of recoverable energy:

	Pounds per person per day	
	1971	1980
U.S. National Average	3.25	3.91
Urbanized Area Average	3.60	4.33

These rates were based upon the estimated 125 million tons of solid waste generated in the U.S. in 1971. The types of waste included in this estimate were described in the text.

Heating Value of Waste

The higher heating value of 4,500 Btu per pound (9 million Btu per ton) is generally accepted as the energy value of "as received," unprocessed waste as delivered by a collection truck to a processing or disposal facility.

Different waste processing methods have different recovery efficiencies. For example, a shredding/air classification waste processing system loses some potential energy by removing heavy combustibles from the fuel fraction, while high temperature incineration with no prior classification would lose far less potential energy. However, no adjustment was made to allow for such processing losses or energy conversion efficiencies (of, say, steam to electricity) because no prejudgment can be made as to which energy recovery method would be used in any given situation.

Population Projections

Series E Projections, indicating a 9.3 percent increase between 1970 and 1980, were used to project the population of the U.S. in 1980. The same projections were applied to all SMSA's, although it is likely that some SMSA's will grow more than others.

Series E Projections are one of the several population projections made by the Bureau of Census, U.S. Department of Commerce based upon projected birth, death, immigration and emigration rates. Series E was selected because it is the best approximation of current rates of birth, death, and so on.

Barrels of Oil Per Day

Energy data are frequently reduced to a common term of measurement to facilitate comparability. British Thermal Units (Btu's) and Barrels per Day of Oil Equivalent (B/DOE) are the most common. B/DOE were calculated based on the following factors:

1 barrel of crude oil = 5.8 million Btu's

1 year = 365 days

EXHIBIT I

Projected Implementations of Energy Recovery Systems by 1980

Location	Tons Per Day	Description
California		
San Diego County	200	Pyrolysis; U.S. EPA is sponsoring project to demonstrate the Garrett Research and Development system; oil produced will be accepted by San Diego Gas and Electric; project in engineering design phase
Connecticut		
Bridgeport	1,200	Solid waste as fuel; State-wide resource recovery authority is reviewing proposals; Northeast Utilities will accept the fuel
District of Columbia	1,000	Solid waste as fuel; D.C., Fairfax County, Arlington County, the City of Alexandria, and the Council of Governments are studying the feasibility of implementing a supplemental fuel system on a region-wide basis; Virginia Electric Power Company and Potomac Electric Power Company are cooperating in the studies
Illinois		
Chicago	2,000	Solid waste as fuel; construction started in early March; Commonwealth Edison will accept the fuel
Chicago area excluding the City	1,000	Solid waste as fuel; several suburbs have approached Commonwealth Edison to determine the feasibility of implementing supplemental fuel systems

Iowa		
Ames	200	Solid waste as fuel; construction to begin by June, 1974; municipal electric utility will accept the fuel
Maryland		
Baltimore	1,000	Pyrolysis; U.S. EPA is sponsoring project to demonstrate the Monsanto system; pyrolysis gas will be combusted on-site to generate steam for sale to Baltimore Gas and Electric; plant will be operational in early 1975
Montgomery County	1,200	Solid waste as fuel; County is planning project with Potomac Electric Power Company cooperation; feasibility study has been completed; County Council and County Executive have approved the plan
Massachusetts		
Braintree	240	Water wall incineration; plant has been operating since 1972; Contract signed early 1974 for sale of steam to Weymouth Art Leather, Co.
East Bridgewater (near Brockton)	1,200	Solid waste as fuel; Combustion Equipment Associates and others; privately financed processing facility; Weyerhauser is accepting the fuel for their industrial steam boilers
Saugus (near Boston)	1,200	Water wall incineration; plant under construction; steam product will be sold to General Electric Co. for process steam
Lawrence	1,000	Solid waste as fuel; Lawrence will be the first implementation under the State-wide solid waste master plan approved in early 1974; master plan calls for supplemental fuel production for steam and steam-electric boilers, and materials recovery

Missouri		
St. Louis	8,000	Solid waste as fuel; Union Electric Company plans to implement, by mid-1977, a system to handle the residential, commercial and selected industrial waste from the entire metropolitan area; U.E. will process raw waste, recover magnetic metal, aluminum, and glass as well as fuel for their boilers
New Jersey		
Essex County (Newark area)	1,000	Solid waste as fuel; Request For Proposals is being prepared; supplemental fuel to be accepted by Public Services Gas and Electric or other industrial steam boilers
Hackensack Meadowlands	2,000	Solid waste as fuel; detailed proposals are currently being reviewed; it is anticipated that the fuel will be accepted by Public Services Gas and Electric or industrial steam boilers
Union County (Elizabeth), or Middlesex County (New Brunswick)	1,000	Solid waste as fuel; feasibility of producing a supplemental fuel for Public Services Gas and Electric is being assessed
New York		
Albany area	500	Solid waste as fuel; feasibility of producing supplemental fuel for industrial steam boilers, state-owned heating plant, and municipal electric utility is being assessed
Hempstead	1,000	Detailed proposals have been received for design and construction of energy and materials recovery systems
Monroe County (Rochester)	500	Solid waste as fuel; feasibility study to produce a supplemental fuel for Rochester Gas and Electric completed; Request For Proposals being prepared

New York City	2,000	Solid waste as fuel; City has completed feasibility study of using City waste as supplemental fuel in Commonwealth Edison's boilers; City writing Request For Proposals to design and construct supplemental fuel facility; City and Commonwealth Edison also plan to initiate contract in Spring 1974 to determine feasibility of designing new steam-electric boiler to burn 50% solid waste
Westchester County (White Plains)	1,500	Feasibility study for solid waste disposal completed; County most interested in energy recovery for County-owned industrial park
Ohio		
Akron	1,000	Water wall incineration; detailed engineering study is underway; steam product will be used for downtown heat and air conditioning and for B.F. Goodrich process steam
Cleveland	500	City has requested and received bids for a steam generation system; the super-heated steam product will be used for electric generation by the municipal utility
Oregon		
Lane County (Eugene)	700	Solid waste as fuel; feasibility study completed to use waste as supplemental fuel in a Eugene municipal steam power plant that currently burns wood waste; additional waste fuel is required because wood wastes are becoming scarce
Pennsylvania		
Philadelphia	2,400	Solid waste as fuel; Combustion Equipment Associates has announced plans to construct and operate, with private financing, a facility to produce supplemental fuel for industrial steam boilers

Puerto Rico		
San Juan	1,000	San Juan planning to initiate feasibility study for a solid waste as fuel system; supplemental fuel would be used by Commonwealth-owned San Juan steam-electric station
Tennessee		
Knoxville	500	Pyrolysis; Tennessee Valley Authority is studying the feasibility of implementing a Torrax gas pyrolysis system to produce gas as supplemental fuel for an adjacent TVA steam-electric boiler
Memphis	500	Solid waste as fuel; detailed proposals have been requested to implement a wet processing system to produce supplemental fuel for a Tennessee Valley Authority steam-electric boiler
Nashville	750	Water wall incineration; construction is complete; public authority has been formed to construct and operate the facility; steam product will be used for downtown heating and air conditioning

Exhibit 2

Rank of Standard Metropolitan Statistical Areas in the United States by Population: 1970

Rank	1970 SMSAs	Population
1	New York, N.Y.	11,571,899
2	Los Angeles-Long Beach, Calif.	7,032 075
3	Chicago, Ill.	6,978,947
4	Philadelphia, Pa.-N.J.	4,817,914
5	Detroit, Mich.	4,199,931
6	San Francisco-Oakland, Calif.	3,109,519
7	Washington, D.C.-Md.-Va.	2,861,123
8	Boston, Mass.	2,753,700
9	Pittsburgh, Pa.	2,401,245
10	St. Louis, Mo.-Ill.	2,363,017
11	Baltimore, Md.	2,070,670
12	Cleveland, Ohio	2,064,194
13	Houston, Tex.	1,985,031
14	Newark, N.J.	1,856,556
15	Minneapolis-St. Paul, Minn.	1,813,647
16	Dallas, Tex.	1,555,950
17	Seattle-Everett, Wash.	1,421,869
18	Anaheim-Santa Ana-Garden Grove, Calif.	1,420,386
19	Milwaukee, Wis.	1,403,688
20	Atlanta, Ga.	1,390,164
21	Cincinnati, Ohio-Ky.-Ind.	1,384,851
22	Paterson-Clifton-Passaic, N.J.	1,358,794
23	San Diego, Calif.	1,357,854
24	Buffalo, N.Y.	1,349,211
25	Miami, Fla.	1,267,792
26	Kansas City, Mo.-Kans.	1,253,916
27	Denver, Colo.	1,227,529
28	San Bernardino-Riverside-Ontario, Calif.	1,143,146
29	Indianapolis, Ind.	1,109,882
30	San Jose, Calif.	1,064,714
31	New Orleans, La.	1,045,809
32	Tampa-St. Petersburg, Fla.	1,012,594
33	Portland, Oreg.-Wash.	1,009,129
34	Phoenix, Ariz.	967,522
35	Columbus, Ohio	916,228
36	Providence-Pawtucket-Warwick, R.I.-Mass.	910,781
37	Rochester, N.Y.	882,667
38	San Antonio, Tex.	864,014
39	Dayton, Ohio	850,266
40	Louisville, Ky.-Ind.	826,553
41	Sacramento, Calif.	800,592
42	Memphis, Tenn.-Ark.	770,120
43	Fort Worth, Tex.	762,086
44	Birmingham, Ala.	739,274
45	Albany-Schenectady-Troy, N.Y.	721,910
46	Toledo, Ohio-Mich.	692,571
47	Norfolk-Portsmouth, Va.	680,600
48	Akron, Ohio	679,239
49	Hartford, Conn.	663,891
50	Oklahoma City, Okla.	640,889
51	Syracuse, N.Y.	636,507
52	Gary-Hammond-East Chicago, Ind.	633,367
53	Honolulu, Hawaii	629,176
54	Fort Lauderdale-Hollywood, Fla.	620,100
55	Jersey City, N.J.	609,266
56	Greensboro--Winston-Salem--High Point, N.C.	603,895
57	Salt Lake City, Utah	557,635
58	Allentown-Bethlehem-Easton, Pa.-N.J.	543,551
59	Nashville-Davidson, Tenn.	541,108
60	Omaha, Nebr.-Iowa	540,142
61	Grand Rapids, Mich.	539,225
62	Youngstown-Warren, Ohio	536,003
63	Springfield-Chicopee-Holyoke, Mass.-Conn.	529,922
64	Jacksonville, Fla.	528,865
65	Richmond, Va.	518,319
66	Wilmington, Del.-N.J.-Md.	499,493
67	Flint, Mich.	496,628
68	Tulsa, Okla.	476,545
69	Orlando, Fla.	428,003
70	Fresno, Calif.	413,053
71	Tacoma, Wash.	411 027
72	Harrisburg, Pa.	410,626
73	Charlotte, N.C.	409,370
74	Knoxville, Tenn.	400,337
75	Wichita, Kans.	389,352
76	Bridgeport, Conn.	389,153
77	Lansing, Mich.	378,423
78	Mobile, Ala.	376,690
79	Oxnard-Ventura, Calif.	376,430
80	Canton, Ohio	372,210
81	Davenport-Rock Island-Moline, Iowa-Ill.	362,638
82	El Paso, Tex.	359,291
83	New Haven, Conn.	355,538
84	Tucson, Ariz.	351,667
85	West Palm Beach, Fla.	348,753
86	Worcester, Mass.	344,320
87	Wilkes-Barre--Hazleton, Pa.	342,301
88	Peoria, Ill.	341,979
89	Utica-Rome, N.Y.	340,670
90	York, Pa.	329,540
91	Bakersfield, Calif.	329,162
92	Little Rock-North Little Rock, Ark.	323,296
93	Columbia, S.C.	322,880
94	Lancaster, Pa.	319,693
95	Beaumont-Port Arthur, Tex.	315,943
96	Albuquerque, N. Mex.	315,774
97	Chattanooga, Tenn.-Ga.	304,927
98	Trenton, N.J.	303,968
99	Charleston, S.C.	303,849
100	Binghamton, N.Y.-Pa.	302,672
101	Greenville, S.C.	299,502
102	Reading, Pa.	296,382
103	Austin, Tex.	295,516
104	Shreveport, La.	294,703
105	Newport News-Hampton, Va.	292,159
106	Madison, Wis.	290,272
107	Stockton, Calif.	290,208
108	Spokane, Wash.	287,487
109	Des Moines, Iowa	286,101
110	Baton Rouge, La.	285,167
111	Corpus Christi, Tex.	284,832
112	Fort Wayne, Ind.	280,455
113	South Bend, Ind.	280,031
114	Appleton-Oshkosh, Wis.	276,891
115	Las Vegas, Nev.	273,288
116	Rockford, Ill.	272,063
117	Duluth-Superior, Minn.-Wis.	265,350
118	Santa Barbara, Calif.	264,324
119	Erie, Pa.	263,654
120	Johnstown, Pa.	262,822
121	Jackson, Miss.	258,906
122	Lorain-Elyria, Ohio	256,843
123	Huntington-Ashland, W. Va.-Ky.-Ohio	253,743
124	Augusta, Ga.-S.C.	253,460
125	Salinas-Monterey, Calif.	250,071
126	Vallejo-Napa, Calif.	249,081
127	Pensacola, Fla.	243,075
128	Columbus, Ga.-Ala.	238,584
129	Colorado Springs, Colo.	235,972
130	Scranton, Pa.	234,107
131	Ann Arbor, Mich.	234,103
132	Evansville, Ind.-Ky.	232,775
133	Lawrence-Haverhill, Mass.-N.H.	232,415
134	Charleston, W. Va.	229,515
135	Raleigh, N.C.	228,453
136	Huntsville, Ala.	228,239
137	Hamilton-Middletown, Ohio	226,207
138	Saginaw, Mich.	219,743

Rank	1970 SMSA's	Population
139	Eugene, Oreg.....	213,358
140	Lowell, Mass.....	212,860
141	Fayetteville, N.C.....	212,042
142	Waterbury, Conn.....	208,956
143	New London-Groton-Norwich, Conn.....	208,412
144	Stamford, Conn.....	206,419
145	Macon, Ga.....	206,342
146	Santa Rosa, Calif.....	204,885
147	Kalamazoo, Mich.....	201,550
148	Montgomery, Ala.....	201,325
149	Modesto, Calif.....	194,506
150	Durham, N.C.....	190,388
151	Brockton, Mass.....	189,820
152	Savannah, Ga.....	187,767
153	Salem, Oreg.....	186,658
154	Wheeling, W. Va.-Ohio....	182,712
155	McAllen-Pharr-Edinburg, Tex.....	181,535
156	Roanoke, Va.....	181,436
157	Lubbock, Tex.....	179,295
158	Terre Haute, Ind.....	175,143
159	Atlantic City, N.J.....	175,043
160	Lexington, Ky.....	174,323
161	Lima, Ohio.....	171,472
162	Racine, Wis.....	170,838
163	Galveston-Texas City, Tex.	169,812
164	Lincoln, Nebr.....	167,972
165	Steubenville-Weirton, Ohio-W. Va.....	165,627
166	Champaign-Urbana, Ill....	163,281
167	Cedar Rapids, Iowa.....	163,213
168	Springfield, Ill.....	161,335
169	Fort Smith, Ark.-Okla....	160,421
170	Green Bay, Wis.....	158,244
171	Muskegon-Muskegon Heights, Mich.....	157,426
172	Springfield, Ohio.....	157,115
173	Topeka, Kans.....	155,322
174	Springfield, Mo.....	152,929
175	New Bedford, Mass.....	152,642
176	Fall River, Mass.-R.I....	149,976
177	Waco, Tex.....	147,553
178	Lake Charles, La.....	145,415
179	New Britain, Conn.....	145,269
180	Asheville, N.C.....	145,056
181	Amarillo, Tex.....	144,396
182	Jackson, Mich.....	143,274
183	Portland, Maine.....	141,625
184	Brownsville-Harlingen-San Benito, Tex.....	140,368
185	Anderson, Ind.....	138,451
186	Provo-Orem, Utah.....	137,776
187	Altoona, Pa.....	135,356
188	Biloxi-Gulfport, Miss.....	134,582
189	Waterloo, Iowa.....	132,916
190	Mansfield, Ohio.....	129,997

Rank	1970 SMSA's	Population
191	Muncie, Ind.....	129,219
192	Petersburg-Colonial Heights, Va.....	128,809
193	Wichita Falls, Tex.....	127,621
194	Ogden, Utah.....	126,278
195	Decatur, Ill.....	125,010
196	Lynchburg, Va.....	123,474
197	Vineland-Millville-Bridgeton, N.J.....	121,374
198	Reno, Nev.....	121,068
199	Fargo-Moorhead, N. Dak.-Minn.....	120,238
200	Norwalk, Conn.....	120,099
201	Pueblo, Colo.....	118,238
202	Kenosha, Wis.....	117,917
203	Bay City, Mich.....	117,339
204	Sioux City, Iowa-Nebr....	116,189
205	Tuscaloosa, Ala.....	116,029
206	Monroe, La.....	115,387
207	Abilene, Tex.....	113,959
208	Boise City, Idaho.....	112,230
209	Lafayette, La.....	109,716
210	Lafayette-West Lafayette, Ind.....	109,378
211	Manchester, N.H.....	108,461
212	Lawton, Okla.....	108,144
213	Wilmington, N.C.....	107,219
214	Gainesville, Fla.....	104,764
215	Bloomington-Normal, Ill..	104,389
216	Tallahassee, Fla.....	103,047
217	Texarkana, Tex.-Ark.....	101,198
218	Fitchburg-Leominster, Mass.	97,164
219	Tyler, Tex.....	97,096
220	Sioux Falls, S. Dak.....	95,209
221	Gadsden, Ala.....	94,144
222	Odessa, Tex.....	91,805
223	Dubuque, Iowa.....	90,609
224	Albany, Ga.....	89,639
225	Billings, Mont.....	87,367
226	St. Joseph, Mo.....	86,915
227	Pine Bluff, Ark.....	85,329
228	Rochester, Minn.....	84,104
229	Sherman-Denison, Tex.....	83,225
230	Great Falls, Mont.....	81,804
231	Columbia, Mo.....	80,911
232	La Crosse, Wis.....	80,468
233	Pittsfield, Mass.....	79,727
234	Owensboro, Ky.....	79,486
235	Danbury, Conn.....	78,405
236	Laredo, Tex.....	72,859
237	Lewiston-Auburn, Maine...	72,474
238	San Angelo, Tex.....	71,047
239	Nashua, N.H.....	66,458
240	Bristol, Conn.....	65,808
241	Midland, Tex.....	65,433
242	Bryan-College Station, Tex.	57,978
243	Meriden, Conn.....	55,959

Exhibit 3

Screening of Standard Metropolitan Statistical Areas (SMSA's)

to Select Potential Candidates in 1974

(CAPITAL LETTERS DESIGNATE POTENTIAL CANDIDATES)

Rank	SMSA	Screening Criteria: Markets	Economics	Public Interest	Comments
1	NEW YORK, N.Y.	Y	F*	A	Critical disposal problem. See Projected Implementations.
2	Los Angeles-Long Beach, Calif.	N	U	A	Ample disposal capacity in canyons. Some development work in methane recovery from landfill.
3	CHICAGO ILL.	Y	F	S	See Projected Implementations.
4	PHILADELPHIA, PA.-N.J.	Y	F	N	See Projected Implementations.
5	DETROIT, MICH.	Y	F	A	New city administration appears receptive to resource recovery. Some private companies recovering their own waste as fuel for their own boilers.
6	San Francisco-Oakland, Calif.	N	U	A	Long-term landfill commitments.
7	WASHINGTON, D.C.-MD.-VA.	Y	F	A	See Projected Implementations. (Washington, D.C. and Montgomery County, Md.).
8	BOSTON, MASS.	Y	F	S	See Projected Implementations. (Saugus, Braintree). Statewide resource recovery plan approved by Governor.
9	PITTSBURGH, PA.	Y	F	N	
10	ST. LOUIS, MO.-ILL.	Y*	F	S	Site of EPA/City/Union Electric demonstration Currently planning to expand. See Projected Implementations.

Rank	SMSA	Screening Criteria: Markets	Economics	Public Interest	Comments
11	BALTIMORE, MD.	Y	F	S	Site of EPA/City/State gas pyrolysis demonstration. See Projected Implementations.
12	CLEVELAND, OHIO	Y	F	A	See Projected Implementations.
13	Houston, Tex.	N	U	N	
14	NEWARK, N.J.	Y	F	A	See Projected Implementations.
15	MINN.-ST. PAUL, MINN.	Y	F	A	State has appropriated $1.5 million in seed money for statewide resource recovery implementation.
16	Dallas, Tex.	N	U	N	
17	Seattle-Everett, Wash.	N	M	A	
18	Anaheim-Santa Ana-Garden Grove, Calif.	N	U	A	
19	MILWAUKEE, WIS.	Y	F	S	State has approved statewide recycling plan.
20	ATLANTA, GA.	Y	F	N	City and DeKalb County are considering use of solid waste as fuel in conjunction with EPA grant for rail haul demonstration.
21	CINCINNATI,O.-KY.-IND.	Y	F	N	
22	PATERSON-CLIFTON-PASSAIC, N.J.	Y	F	A	
23	SAN DIEGO, CALIF.	E	M	S	Site of EPA/County oil pyrolysis demonstration. See Projected Implementations.
24	BUFFALO, N.Y.	Y	F	S	Erie County is considering recycling plan.
25	MIAMI, FLA.	E	F*	A	

[illegible]	SMSA	Screening Criteria: Markets	Economics	Public Interest	Comments
[illegible]	Kansas City, Mo.-Kans.	N	U	N	
27	DENVER, COLO.	Y	M	S*	
28	San Bernadino-Riverside-Ontario, Calif.	N	U	A	
29	Indianapolis, Ind.	Y	U	N	
30	San Jose, Calif.	N	U	A	
31	New Orleans, La.	N	U	N	New Orleans is planning a materials recovery system, but combustible fraction will be landfilled.
32	Tampa-St. Petersburg, Fla.	N	M	N	
33	PORTLAND, ORE.-WASH.	N	M	S*	
34	Phoenix, Ariz.	N	U	N	
35	COLUMBUS, OHIO	Y	M	A	
36	PROVIDENCE-PAWTUCKET WARWICK, R.I.-MASS.	Y	F	S	Governor and State Legislature are studying the feasibility of a statewide recycling system.
37	ROCHESTER, N.Y.	Y	F	A	See Projected Implementations.
38	SAN ANTONIO, TEX.	Y	F	A	Municipally-owned utility is planning to build a coal-fired boiler to handle solid waste.
39	Dayton, Ohio	Y	M	A	
40	LOUISVILLE, KY.-IND.	Y	M	S	
41	Sacramento, Calif.	N	M	A	

Rank	SMSA	Screening Criteria			Comments
		Markets	Economics	Public Interest	
42	MEMPHIS, TENN.-ARK.	Y	F	S	See Projected Implementations.
43	Fort Worth, Tex.	N	U	N	
44	Birmingham, Ala.	Y	U	N	
45	ALBANY-SCHENECTADY-TROY, N.Y.	Y	F	S	See Projected Implementations.
46	TOLEDO, OHIO-MICH.	Y	F	A	
47	Norfolk-Portsmouth, Va.	Y	U	A	
48	AKRON, OHIO	Y	F	A	
49	HARTFORD, CONN.	Y	F	S	Statewide recycling program in effect.
50	Oklahoma City, Okla.	N	U	N	
51	Syracuse, N.Y.	Y	U	N	
52	GARY-HAMMOND-EAST CHICAGO, IND.	Y	F	N	
53	Honolulu, Hawaii	N	F	A	
54	Fort Lauderdale-Hollywood, Fla.	N	F	N	
55	JERSEY CITY, N.J.	Y	F	A	
56	Greensboro--Winston-Salem--High Point, N.C.	Y	U	A	
57	Salt Lake City, Utah	N	U	N	

Rank	SMSA	Screening Criteria: Markets	Economics	Public Interest	Comments
58	Allentown-Bethlehem-Easton, Pa.-N.J.	Y	U	M	
59	NASHVILLE-DAVIDSON, TENN.	E	F	S	See Projected Implementations.
60	Omaha;Nebr-Iowa	Y	M	N	
61	Grand Rapids, Mich.	Y	U	A	
62	Youngstown-Warren, Ohio	Y	U	N	
63	Springfield-Chicopee-Holyoke, Mass.-Conn.	Y	U	S	
64	JACKSONVILLE, FLA.	E	F	S	Municipally-owned utility is seeking solution to common problems of waste disposal and power generation.
65	Richmond, Va.	Y	U	N	
66	WILMINGTON, DEL.-N.J.-MD.	Y	F	S	Site of EPA/State of Delaware resource recovery demonstration.
67	Flint, Mich.	Y	U	N	
68	Tulsa, Okla.	N	U	N	
69	Orlando, Fla.	N	M	N	
70	Fresno, Calif.	N	U	A	
71	Tacoma, Wash.	N	U	N	
72	Harrisburg, Pa.	Y	U	N	
73	Charlotte, N.C.	Y	U	N	
74	KNOXVILLE, TENN.	Y	M	S	See Projected Implementations.

Rank	SMSA	Screening Criteria: Markets	Economics	Public Interest	Comments
75	Wichita, Kans.	N	U	N	
76	BRIDGEPORT, CONN.	Y	F	S*	Site of first implementation of statewide recycling program. See Projected Implementations.
77	Lansing, Mich.	Y	U	N	
78	Mobile, Ala.	Y	U	N	
79	Oxnard-Ventura, Calif.	N	U	A	
80	Canton, Ohio	Y	U	N	
81	Davenport-Rock Island-Moline, Iowa-Ill.	Y	U	N	
82	El Paso, Tex.	N	U	N	
83	NEW HAVEN, CONN.	Y	F	S*	Statewide recycling plant in effect.
84	Tuscon, Ariz.	N	U	N	
85	West Palm Beach, Fla.	N	M	N	
86	Worcester, Mass.	Y	U	A	
87	Wilkes Barre - Hazelton, Pa.	Y	U	N	
88	PEORIA, ILL.	Y	U	S*	
89	Utica-Rome, N.Y.	Y	U	N	
90	York, Pa.	Y	M	N	
91	Bakersfield, Calif.	N	U	N	

Rank	SMSA	Screening Criteria: Markets	Economics	Public Interest	Comments
92	LITTLE ROCK-NORTH LITTLE ROCK, ARK.	Y	F	S	
93	Columbia, S.C.	Y	U	N	
94	Lancaster, Pa.	Y	M	N	
95	Beaumont-Port Arthur, Tex.	N	U	N	
96	Albuquerque, N. Mex.	N	U	N	
97	CHATTANOOGA, TENN.-GA.	Y	M	S*	
98	Trenton, N.J.	Y	M	N	
99	Charleston, S.C.	Y	U	N	
100	Binghamton, N.Y.-PA.	Y	U	N	

With the exception of the SMSA's listed below, none of the SMSA's ranked lower than 100 was characterized by economic or public interest conditions in 1974 that would favor resource recovery by 1980. Some of the SMSA's not listed were close to potential waste fuel markets, but this by itself was not enough to consider an SMSA as a Potential Candidate. The following SMSA's are also Potential Candidates:

106	MADISON, WIS.	Y	M	S*	Shredding operation underway. Statewide recycling program recently approved.
116	ROCKFORD, ILL.	Y	M	S*	
133	LAWRENCE-HAVERHILL, MASS.	Y	F	S*	Site of first recycling facility under newly approved statewide recycling program.
134	CHARLESTON, W.VA.	Y*	M	A	Union Carbide is building a 200 ton per day pyrolysis demonstration plant.
139	EUGENE, OREG.	Y	F	S*	See Projected Implementations.
151	BROCKTON, MASS.	Y*	M	A	See Projected Implementations.

LEGEND for Exhibit 3

Markets

Y — Yes, electric utility boilers with ash handling capability are available.

N — No, electric utility boilers with ash handling capability are not available.

E — Exception. Ash-handling electric utility boilers are not available but this SMSA has made other arrangements. See text.

Economics

F — Favorable economic condition for resource recovery. Generally this is an indication that conventional incineration is too expensive and that land for disposal is probably not available because of population density, high water table, or political opposition to a new disposal site.

M — Marginal economic conditions. The economic conditions may be conducive to resource recovery.

U — Unfavorable economic conditon for resource recovery. Generally this means that land is available for disposal.

Public Interest

S — Strong. Public interest in resource recovery is desired even if economic conditions are unfavorable or marginal.

A — Adequate public interest.

N — Nominal public interest.

O — Strong interests oppose resource recovery.

*This factor was significantly more important than other factors in the decision to designate this SMSA as a Potential Candidate.

APPENDIX III

NATIONAL ENERGY SAVINGS FROM MATERIAL RECYCLING: SOME "MAXIMUM POSSIBLE" ESTIMATES FOR FERROUS METAL, ALUMINUM AND GLASS

by Frank A. Smith

INTRODUCTION

This appendix presents estimates on the potential energy savings from recycling the aluminum, ferrous, and glass fractions of post-consumer residential and commercial solid waste over the time frame 1972-1990. The basic issue is how much energy could be saved on a nationwide basis from the recycling of these three waste materials as substitutes for their virgin material counterparts (i.e., ferrous waste for virgin pig iron, etc.), under what might be referred to as the "maximum possible recovery scenario." This is an attempt to set some practical recycling level within the theoretical quantity limit of total waste generation, but without pretending to consider political or economic obstacles as limits to recovery. Results are summarized for aluminum, ferrous, and glass in Table 1.

ASSUMPTIONS

Without going into great detail, the following basic estimates and assumptions underlie the derivation of these results.

1. Total "available" post-consumer waste quantities were projected on the basis of recent EPA estimates of the ferrous, aluminum and glass fractions of residential and commercial solid waste streams, and unpublished contract work by Midwest Research Institute on baseline forecasts. Construction, demolition, industrial, and other possible waste flow sources of material recovery were not considered.

2. Percentage of Waste Material processed for recovery was taken as 100% of the waste generated in Standard Metropolitan Statistical Areas. This amounts to roughly 70 to 74% of total U.S. generation between 1972 and 1974.

3. Recovery process efficiencies were assumed as follows, based on research by Midwest Research Institute:

   Aluminum 65 - 75%
   Ferrous 90%
   Glass 70%

4. Energy savings per ton of material recycled were taken as follows, based on an assessment of available literature and current ongoing contract work, (in 10^6 Btu/ton of material recovery):

   Aluminum 200
   Ferrous 12
   Glass 1.3

CONCLUSIONS

The "maximum possible" energy savings values presented in Table 1 are smaller than many would have guessed, and are in some cases significantly less than other published estimates (e.g. see the report of the National Commission on Materials Policy as well as EPA's First Annual Report to Congress on Resource Recovery). Others have based their estimates on 100% recovery from a larger estimated waste stream, and/or have used higher unit energy savings multipliers for certain materials. There is still much to be learned about this latter question, but the values used here are believed to be the best and most recent presently available engineering estimates.

On the other hand, many will consider our assumption of 100 percent processing of all metropolitan area waste as a very extreme case. And they would, of course, be correct. The objective was to get a first-order approximation to the maximum possible recovery as an upper bound for purposes of discussion and policy input. Later work will be directed not only at "firming-up" these values, but also at providing further evaluation of more realistic expectations.

Whether one thinks the 1972 figure of 172 trillion Btu's is a small or a large number depends on perspective. It is about 0.25% (one-quarter of one percent) of the nation's primary energy (fossil fuel plus hydroelectric plus nuclear) consumption for 1972 (approximately 70,000 trillion Btu). At 5.8 million Btu's per barrel of crude oil, 172 trillion Btu's is equivalent to about 30 million barrels of crude oil. This potential crude oil equivalent would rise to almost 50 million barrels by 1980 and 70 million barrels by 1990.

TABLE 1

NATIONAL ENERGY SAVINGS FROM MAXIMUM POSSIBLE RECYCLING OF ALUMINUM, FERROUS, AND GLASS FRACTIONS OF POST-CONSUMER SOLID WASTE [TRILLIONS OF BTU'S]*

Materials**	1972	1975	1980	1985	1990
Aluminum [46-56%]	82	115	164	212	274
Ferrous [63-67%]	81	87	95	107	116
Glass [50-52%]	8	13	15	16	16
Total Energy	172	215	274	335	406

*Energy savings are based on "total system" analyses which include primary energy required for raw material acquisition and electricity input as well as for principal refining processes.

**Figures in brackets indicate percentages of the individual material in nation-wide solid waste assumed to be recoverable from a "maximum possible" recovery effort. Lower percentages are for earlier years, higher percentages for later years when larger proportions of popula- is expected to reside in SMSA's and when extraction efficiency expected to rise. Recovery quantities based on residential and commercial solid waste only.

μσ1045

*U.S. GOVERNMENT PRINTING OFFICE: 1974 582-412/9 1-3

SW 125

SW 125

Energy conservation through improve

AUTHOR

solid waste management

TITLE

DATE LOANED	BORROWER'S NAME	DATE RETURNED