How Big Should a New Energy Recovery Facility Be?

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INTRODUCTION

Careful attention must be paid to characterizing the municipal waste stream, both now and in the future, if the capacity (size) of waste management facilities are to be optimized for economic and environmental benefits. This is particularly important for municipal waste combustion facilities where significant capital expenditures are required before any waste can be handled. Too large a facility can bring undue financial strain; too small a facility will create a need for more landfill capacity reducing the potential benefits of energy recovery and increasing the long-term release of methane, a potent greenhouse gas, from these materials.

Modern waste management systems seek to obtain a least cost solution while maintaining environmental objectives. To meet these requirements, modern systems include elements of reduction; diversion through recycling or reuse; and disposal, including energy recovery and landfilling. The exact proportion of materials handled by each of these alternatives is a function of the characteristics of a community's waste stream and the economics of applying the various alternatives. Managers need to evaluate the concerns of local citizens to arrive at the best solution for their community. More and more, these managers are coming to appreciate that waste is like any other commodity in our society—it creates a monetary dynamic that influences management decisions.

As more waste is generated, municipalities can move to modify the system by raising tipping fees or taxes, but this can have undesired effects. For example, several years ago Metropolitan Toronto increased landfill tipping fees for commercial users. In response, these users simply transported more waste to the United States. Local revenues dropped and the overall public cost of waste disposal increased because commercial revenues no longer offset comparatively expensive local recycling programs. In addition, the reduced rate of landfilling delayed closing of some landfills because materials were no longer available to complete the closure plan.

Other examples of unexpected results from interventions in waste management systems can be cited. The German "green-dot" system sought to separate consumer packaging from the waste stream by requiring that manufacturers deal with these materials. This did not reduce the cost to society—it merely shifted the point of payment. The "green-dot" system led to a glut of material on the recycling market. In October 1996, Germany enacted the Closed Cycle Economy Law. This law put material recycling and waste combustion with energy recovery on an equal footing. The recycling industries that grew over the past few years in response to the artificially created need to recycle materials irrespective of cost or true societal benefit may now face economic ruin as waste flows to the most cost effective management alternative.

Different waste management alternatives can also be selected to address environmental concerns, but these selections can also effect the ultimate mix of waste disposal options. For instance, European countries are moving towards limiting the level of carbon in waste deposited in landfills to minimize both future ground water pollution and greenhouse gas emissions. In turn, this is increasing the demand for waste combustion with energy recovery.

The suggestion that municipal waste combustion (MWC) with energy recovery might become part of a community's solid waste management system usually draws negative response. Some of the criticisms originate from genuine concerns about the effects such projects might have on the environment and human health. Other criticisms are based on the belief that incinerators, a major capital expense, will become a financial burden to an unwary community. Some even suggest that incineration will encourage a sense of complacency among those who should be striving to reduce the volume of the waste stream. Since the MWC must have enough fuel for economic operation, this last argument goes, MWCs discourage 3-R activities--reduction, reuse and recycling--by requiring all the available MSW to feed its insatiable appetite.

Many of these concerns have a basis in fact. Comparatively higher emissions characterized many older MWCs; however, state-of-the-art facilities now have such low emissions that conventional stack testing methods must be modified to even detect emitted compounds. Excessive costs characterize facilities built on unreasonable expectations (i.e., future waste growth, explosive energy price increases, or technically impossible performance). Creative analysis of the amount of waste that can be diverted through innovative 3-R initiatives are frequently used to support the theory that there is not enough material for all management options to co-exist. This argument falsely presumes that no prudent amount of MWC capacity can co-exist with 3-R activities in a given waste shed.

While most people would like to select the optimal set of waste management alternatives for their community, they are faced with the problem of determining the highest or best use of the materials in their waste stream. There are, unfortunately, no universally acceptable standards for making this decision. This evaluation uses a responsible and prudent guideline — build MWCs to handle what is likely to be left after application of the 3-R's — to reach the conclusion that MWCs and the 3-R's are compatible as long as the materials and resources which have a higher and better use are reduced, reused, or recycled instead of being recovered (incinerated at an energy recovery facility). This paradigm leads to the conclusion that it is certainly safe to build MWC capacity equal to half a waste shed's current disposal needs and it is probably justified to equal today's disposal requirements.

MUNICIPAL SOLID WASTE CHARACTERISTICS

The starting point for estimating future effects of various 3-R strategies is a comprehensive picture of today's waste stream. The amount and nature of solid waste generated in a community depends not only on population, season and business economic cycle, but also the demographics of the community. The 1991 Gore & Storrie study[1] of MSW composition and generation rates in different Ontario communities clearly shows these effects.

Not only is it necessary to know what is in the waste stream, but it is also necessary to know how much material is already being removed. Projections of waste and composition over the planning cycle must account for these factors, especially since they form the basis for evaluating management options. The potential effects of reduction, reuse and recycling initiatives must be combined with the future quantity estimates to establish the amount and characteristics of the residual (post 3-R) waste requiring management.

Composition

Most people associate MSW with the materials discarded directly by households. However, in actual practice, it also includes the employment related solid wastes discarded by industrial, commercial and institutional (ICI) sources. Such material resembles the residential waste stream because it contains newspapers and magazines, beverage cans, and food wastes. Process waste streams coming from industrial sources like foundry sand, prompt (in-house) steel making scrap and chemicals, etc. are not usually considered to be MSW. Construction and demolition debris (C&D) is MSW only in a very general sense, since the characteristics of the debris are so different from household wastes. Consistent with the pioneering work done by Bird and Hale[2] to characterize municipal discards in Canada, in this paper we consider only the residential and ICI wastes that would be targeted for reduction, reuse, recycling and, lastly, recovery.

Only limited field data exists for Ontario waste composition; there have been few published reports of detailed waste stream evaluations in Ontario after 1980. As a starting point in this evaluation, Ontario based data were modified using information from various other studies that characterized 3-R materials to account for changes that have occurred since the base data were gathered. Incidentally, since most of Canada and the United States share a generally common heritage and have many common expectations, the MSW streams are generally similar.

The Bird and Hale baseline data represents the composition of MSW in the late 1970s. Recognizing that changes in the economy and the use of different materials leads to a changing mix in the waste, it is necessary to adjust the 1980 figures for both effects. Using the sectorial generation rates from Franklin Associates[3], the 1980 levels were escalated to 1990. These were then adjusted using The WASTE Program[4] data, a sampling and analysis program undertaken in suburban Vancouver, British Columbia in 1991 which developed a comprehensive picture of waste received at an MWC. However, since The WASTE Program's data include the effect of Vancouver's successful blue-box program, this influence was factored out. Next, using the results of the year-long 1990 multi-borough sorting study in New York City[5], the Vancouver composition information was adjusted to reflect gross discard levels. The resulting estimated 1990 municipal solid waste composition for Ontario is shown in Table 1. The projected distribution of materials in Ontario's 1990 MSW stream shown in Table 1 are generally consistent with the 1991 Gore & Storrie results for the residential solid waste sampled in southern Ontario.

Table 1 contains projections of the waste stream composition for both the years 2000 and 2010. The waste mix changes over the years due to differences in sectorial generation rates. A good example of the effects of the sectorial generation rate shifts is the increased amount of plastic in the 1991 waste stream compared to that present in 1980. This has been matched by a decline in glass and ferrous metal packaging over the same time period.

The analysis in this report deals solely with changes that will occur in the composition and quantity of 100 kg of waste placed at curbside in 1990 as compared to that present in 2000 and 2010. It assumes that trends in waste generation seen over the past decades will continue; however, it also reflects changes in society's willingness to divert material from the disposal alternative.

The percentages in Table 1 represent the proportion of the individual components present in either the Gross or Net Discards. To calculate the Net Discards, the Gross Discards level outlined in the preceding paragraphs was adjusted to reflect recycling rates. The Gross Discard rates were adjusted for each of the subsequent periods to develop the basis for estimating waste composition at those times. An additional factor, population growth, has been disregarded in the present analysis. The Gross Discards in 1990 would have been 114 kg for every 100 kg of solid waste placed at the curb. By 2000, the Gross Discards are projected to grow to 128 kg and by 2010 to 145 kg of solid waste. The Net Discards for these periods will vary as a function of the success of diversion programs.

Impacts of Reduction, Reuse and Recycling

Reduction, reuse and recycling all conserve resources and minimize the amount of material left over for ultimate disposal. Various strategies exist to accomplish high diversion rates. For example, Table 2 includes British Columbian data which suggest that high deposits on containers result in excellent recovery rates. We have assumed that recycling could expand to look more like the British Columbia situation.

We have also assumed that recycling will increase from today's level. Present recycling rates can be characterized as the median rates from the 1991 Gore & Storrie study in Ontario. Estimates of the potential extent of recycling extend to between the low and the high recycling estimates for the year 2000 prepared by the USEPA and used in their Report to Congress, but could be further extended to include those identified by the Center for the Biology of Natural Systems (CBNS) that suggests higher rates are possible by 2010.

If entire communities are as motivated as true believers, and cost is not a consideration in an era of competing demands on public funds, the major difference between the high and low estimates is the inclusion of more types of recycled materials in later years. By 2010, 25% of the books, boxboard, diapers and mixed paper and 37% of the assorted plastics in categories 3 to 7 might be recycled. Also, half the wood and lumber and food wastes are assumed to be diverted by 2010. Achieving these recycling rates is dependent upon many things, not the least of which is the technical and economic feasibility of recycling some of these materials. Some of these considerations are contained in the following section.

Recycling Combustibles. Combustibles are the part of the municipal solid waste stream. They are broadly classified as:

- forest products (paper, cardboard and boxboard),
- derived from fossil fuels (plastics and waxes),
- yard and garden waste (grass, leaves, brush, stumps, etc.),
- food preparation waste (garbage for want of a better word), and
- textiles.

Paper Products. As may be expected, each time paper is recycled, some of the fibre is lost because it becomes too short to be recovered. The remaining fibre is somewhat oxidized causing it to lose some of its strength and become more brittle. Consequently, there is a limit to both the number of times fibre can be recycled and the amount of recycled fibre that can be used in new paper products without seriously degrading the product's properties. It is estimated that 15 to 25% of the recycled paper volume will end up as waste from the process[6]. This reality implies that it is not necessary to worry about recovering 100% of the paper products; only a certain amount, albeit a large fraction, of recycled fibre can be utilized even after worldwide fibre recovery capacity is fully expanded.

Plastics. Plastics are also recyclable combustibles. While research is underway to develop processes which can dissolve mixed plastics and recover their individual resins, the current method of recycling is to physically separate the recovered items by plastic type and colour for reuse. Thus, today's recycling methods address the relatively pure plastics used in packaging and food service applications, but they do not manage engineered plastics used in housewares and toys. They also do not address the special plastics found in video tapes, records, disks and diskettes. Current initiatives will likely lead to new technologies; but for the foreseeable future, a residual, not readily recyclable, plastics stream is likely to remain.

Textiles. This category is made up of textiles, rubber and shoes. The amount of rubber is small and includes tires, inner tubes, hockey pucks and soccer ball bladders. There is a ready market for used natural and synthetic textiles, so much of this category can be recycled. We are unaware of any use for worn-out shoes and know that they do not readily compost.

Yard and Garden Waste. The grass component is made up of grass and leaves and the simple expedient of using a mulching mower or having a back-yard compost heap (provided they are legal and properly operated to avoid nuisances) will eliminate much of this category. The brush category includes stumps, trunks and branches. While these may be usable in fireplaces, a substantial chipper is needed to convert this material into mulch or bulking agent for composting so collection is the most likely alternative for most of this material. The wood category can be similarly chipped and used if it is not impregnated with fungicides or coated with lead based paints.

Recycling Noncombustibles. Metals and glass are readily recyclable provided they are separated into marketable categories. Aluminum and tin cans are very high grade feed stock for making new aluminum and steel products. Other metals, like copper wiring and brass plumbing fixtures, are also recyclable once any organic coatings are removed.

While there are limited uses for mixed colour cullet in glass making, colour sorted glass has a much wider use. The market for coloured glass is limited. It is not used as much in North American packaging as it is in Europe and importing products in green and brown glass containers to North America leads to an accumulation of these materials.

Projections of Waste Composition and Quantity

As the foregoing shows, there is a wide potential for employing various techniques to reduce the MSW stream. Forecasting the characteristics and quantities of future MSW streams is not an exact science. Indeed, for the purposes of this assessment, precisely defining the future is unnecessary. Rather, we should use the estimated extremes to bracket future reality. Thus, the results presented here represent reasonable bounds for levels of reduction, reuse and recycling likely to be achieved by the years indicated.

The recycling rates shown in Table 3 include an allowance for both contaminated materials which become dirty through reuse and are not suitable for recycling and for the proportion of people who, after any amount of education and inducement, simply will not or do not comply with the recycling guidelines. Figure 1 estimates MWC composition and the changes in discard quantity over time:

- In 1990, every 100 kg of MSW at the curb would represented an average of 114 kg of waste generated.
- By 2000, the Gross Discards will be 128 kg. Depending upon the level of recycling achieved, between 92 and 61 kg will remain to be set out at the curb.
- By 2010, Gross Discards will rise to 145 kg. Again, depending upon the level of reduction, reuse and recycling achieved, between 103 and 53 kg will remain for ultimate disposal.

Because the estimates bracket the range of anticipated diversion effectiveness, we would not expect to have more post 3-R waste than is shown in Figure 1 under the low recycling (high net disposal) scenario. Nor would we expect to have less post 3-R waste than is shown under the high recycling (low net disposal) scenario.

Figure 2 shows the composition of municipal solid waste in 2010. Extensive 3-R management activities are expected to remove between 35 and 70 kg of paper for every 100 kg of waste currently discarded. The amount of food waste will be cut in half, to some extent as the result of less spoilage and wastage due to improved packaging, and the balance due to composting and in-sink garbage grinders. Material that is not diverted does not lend itself to alternative disposal. Either it should not be composted in residential settings (meat scraps and fat attract vectors and scavengers and create a public health problem) or it is bones and the like which do not compost well. Glass recycling is projected to increase as is the recycling of plastic containers and films. Yard waste is expected to be substantially reduced through the use of mulching lawn mowers, backyard composting and separate municipal collection of yard waste. Textiles will be recycled as well.

Having developed a description of the MSW stream in 2010, the issue of using MWC technology can be addressed.

INCINERATION'S PERCEIVED EFFECTS ON THE PUBLIC'S MOTIVATION TO CONSERVE

Incineration, whether in an energy recovery facility or in a mass destruction box, can be viewed as a simple solution to solid waste disposal. With an MWC available, people may feel that they do not have to participate in recycling programs because their waste is being volume-reduced prior to landfilling. Also, if an incinerator is available, the public is aware that existing landfill capacity can be extended by a factor of 5 to 10. As a consequence of this perception, many 3-R supporters feel that if incineration is encouraged, a moral incentive to reduce, reuse, and recycle is removed.

Incinerators are also perceived as insatiable monsters. This historical perception is the result of the method of financing prevalent in the United States. Many, if not most, U.S. incinerators are industrial revenue bond financed. As part of the financing package, the users pledge to deliver enough waste to the facility to keep it full. This pledge, when coupled with an energy purchase contract and technical (performance) guarantees, provides, in effect, a revenue guarantee that secures the debt. Thus, the basis for the argument, "If the 3-Rs are promoted, these communities face financial ruin because the anticipated revenues are not realized".

While the existence of these perceptions cannot be disputed, the reality is that as long as the MWC is properly sized, there is no conflict. The facility cannot process waste beyond its capacity, so 3-Rs are needed to extend landfills to the greatest extent. Also, in a comprehensive waste management system, the MWC recovers energy that would otherwise be lost and acts as a final hurdle for solid waste to clear before burial. Properly sized, incinerators ensure maximum recovery of materials and energy and minimum depletion of the landfill resource.

Effect of Changed Solid Waste Composition and Fuel Properties

Table 3 is a summary of the post 3-R discards fuel properties. These were estimated by combining individual component properties in proportion to the amount of each present. As diversion strategies are implemented, the first impact is to remove non-combustible recyclables. This has the effect of reducing fuel ash content and increasing the heating value. As diversion implementation continues, combustibles like paper and are targeted. These remove energy content and also reduce ash levels so the net impact is only a slight decrease in heating value. Assuming an extensive, CBNS type intensive diversion effort is put in place, the projected heating value actually rises because a relatively greater percentage of the waste is engineered and other plastics which do not presently have technically viable recycling options.

As the fuel properties change, so does the sustainable capacity of the incinerator facility in tonnes per day. The energy recovery capacity is fixed by the boiler design and physical installation, only so many joules of energy can be fed to the system within a given time frame. Changes in waste composition and waste chemistry result in changes in daily throughput capacity. In terms of tonne per day nameplate capacity, an incinerator built for today's waste will only handle 91-95 percent of the designed tonnage if it is being fed the year 2000 waste mix and 90-98 percent of design tonnage when fed the year 2010 mix. The residues produced, including moisture added for dust control and lime from the acid gas control system, will decrease 8 to 10 percent with low levels of recycling and increase 15 to 40 percent with high recycling rates compared to the residue generated in 1990.

COMPATIBILITY ASSESSMENT

As the 3-Rs are implemented, less material remains to be incinerated. The bottom line is that even if we can afford and induce the general public to reduce, reuse and recycle waste to the extent contemplated by advocates of CBNS, we will only reduce the amount requiring ultimate disposal to 1/3 to 2/3 of the amount generated before application of the 3-Rs. That is, an MWC designed to recover the energy content and recycle the residual metals and ash from about half of today's collections will likely still be needed in 2000 and 2010 under the most aggressive scenario analyzed. In reality, a capacity equal to today's net discards may actually be needed to accommodate the residual waste stream after reasonable diversion efforts.

Another way to look at prudent capacity is to ask how much of the residual solid waste collections (not picked up as a part of a 3-R program) will be needed to support a plant designed to handle today's solid waste stream. Answering this question requires considering the changes in waste fuel properties as a result of 3-R implementation and changes in waste characteristics over time.

The fuel properties govern how much solid waste can be burned in an incinerator because these systems are not tonnage devices, they are usable energy devices. An energy recovery incinerator cannot consume more waste than its energy recovery equipment is capable of removing. While contrary to convention, EFW's should be rated in kg/h of steam raised or mWe generated, not tonnes per day.

Figure 3 illustrates the effect of recycling and changing fuel characteristics on heating value. Note that, regardless of the level of recycling accomplished, the energy value increases between 1990 and 2010. Municipal solid waste has been changing. In the early 1980s, 10,500 kJ/kg (4,500 Btu/lb) was considered a typical heating value for as-discarded MSW. Today, we believe that MSW typically displays a heating value around 12,800 kJ/kg (5,500 Btu/lb). As 3-Rs are implemented, the heating value is expected to continue to rise. The increase in heating value, however, is from around 12,800 kJ/kg (5,500 Btu/lb) to around 14,000 kJ/kg (6,000 Btu/lb) — an increase that is much less than that already successfully handled by operating MWCs. At the same time, the ash content of as-discarded MSW will rise or fall depending on the effectiveness of 3-R programs with increasing effectiveness resulting in more ash which translates to more residue.

Figure 4 shows that a plant designed to process 100 TPD of as-collected municipal solid waste today will be able to process between 90 and 95 TPD of as-collected MSW in 2000. The exact value depends upon the extent of 3-R implementation and its impact on the final fuel properties. That same plant will be able to process between 90 and 98 TPD of as-collected MSW in 2010.

CONCLUSION

This paper provides a projection for the amount and composition of waste likely to be available in future years from a fixed population. The projection shows that under the low recycling scenario, if incinerator capacity equal to today's generation rate were built, recycling would accommodate the growth in waste production. If we take the high recycling rate projection, a need will remain for managing about half the waste that is currently being put out at the curb.

These projections do not account for widening the waste shed area, nor do they account for increases in population between now and 2010. The projections suggest that reasonably sized incinerator facilities can co-exist with even the most intensive recycling, reduction and reuse activities.

If we were to build enough capacity to recover the energy in half the waste collected today, that capacity should remain full into the foreseeable future. Even with maximum 3-R implementation, some waste will still go to the landfill without energy recovery and unrecycled metals will be lost to the disposal site. With minimum expected 3-R implementation, incinerator capacity equal to today's disposal will be needed instead of the half indicated under the maximum 3-R scenario.

Certainly reasonable amounts of energy recovery capacity, say equal to half of today's discards, will be needed, regardless of the success of 3-R programs.

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Table 1. Estimated MSW composition for Ontario in 1990 and subsequent years.

	1990 DISCARDS		2000 DISCARDS			2010 DISCARDS		
PARTITIONED CATEGORIES	GROSS	NET	GROSS	HIGH NET	LOW NET	GROSS	HIGH NET	LOW NET
Paper	63.23	53.88	76.56	46.18	19.35	92.06	55.28	21.10
Kraft & Corrugate	19.13	19.13	23.05	11.98	2.30	27.91	14.51	2.79
Newsprint	13.82	4.47	15.51	8.07	1.55	17.34	9.01	1.73
Fine Paper	14.26	14.26	19.92	10.36	1.99	25.57	13.30	2.56
Magazines & Glossy	2.13	2.13	2.45	1.27	0.24	2.94	1.53	0.29
Books & Phonebooks	1.31	1.31	1.50	1.50	1.50	1.80	1.80	1.35
Boxboard	2.00	2.00	2.30	2.30	2.30	2.75	2.75	2.07
Diapers	2.31	2.31	2.31	2.31	2.31	2.31	2.31	1.74
Mixed Paper	8.28	8.28	9.52	8.38	7.14	11.43	10.06	8.57
Glass	5.21	4.10	4.29	2.61	1.84	3.84	2.39	1.73
Beer Bottles	0.06	0.00	0.04	0.00	0.00	0.04	0.00	0.00
Softdrink--Refillable	0.65	0.65	0.49	0.01	0.00	0.42	0.00	0.00
Softdrink--Non-refillable	0.75	0.75	0.57	0.07	0.01	0.49	0.06	0.01
Liquor & Wine	0.87	0.31	0.66	0.37	0.07	0.56	0.32	0.06
Containers--Food	1.12	0.62	0.85	0.48	0.08	0.73	0.42	0.07
Containers--Other	0.37	0.37	0.35	0.35	0.35	0.33	0.33	0.33
Flat & Cullet	1.40	1.40	1.33	1.33	1.33	1.26	1.26	1.26
Ferrous Metals	4.13	3.66	3.84	3.30	3.05	3.63	3.22	3.03
Beer Cans	0.06	0.01	0.05	0.01	0.00	0.04	0.00	0.00
Softdrink Cans	0.04	0.03	0.03	0.01	0.00	0.02	0.00	0.00
Food Cans	1.22	0.82	0.95	0.48	0.24	0.73	0.37	0.18
Other	2.81	2.81	2.81	2.81	2.81	2.84	2.84	2.84
Non-ferrous Metals	1.19	0.85	1.44	0.78	0.43	1.44	0.75	0.42
Beer Cans	0.38	0.04	0.41	0.05	0.00	0.46	0.05	0.00
Food Containers & Foil	0.36	0.36	0.46	0.23	0.00	0.44	0.22	0.00
Manufactured Aluminum	0.42	0.42	0.53	0.47	0.40	0.50	0.44	0.38
Other Non-ferrous	0.03	0.03	0.04	0.04	0.03	0.04	0.04	0.03
Plastics	8.47	7.36	11.00	9.31	9.20	12.81	10.82	9.43
Container--1(PETE)	0.09	0.01	0.16	0.01	0.00	0.17	0.02	0.00
Container--2(HDPE)	1.14	0.11	1.62	0.08	0.00	1.92	0.10	0.00
Container--3(PVC)	0.04	0.04	0.06	0.05	0.03	0.08	0.06	0.04
Container--4(LDPE)	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.03
Container--5(PP)	0.16	0.16	0.22	0.22	0.22	0.26	0.26	0.17
Container--6(PS)	0.02	0.02	0.04	0.04	0.04	0.04	0.04	0.03
Container--7(other) & Unidentified	0.10	0.10	0.14	0.14	0.14	0.16	0.16	0.10
Film & Bags	1.95	1.95	2.47	2.47	2.47	2.87	2.87	1.81
Housewares	4.24	4.24	5.37	5.37	5.37	6.24	6.24	6.24
Toys	0.69	0.69	0.87	0.87	0.87	1.01	1.01	1.01
Tapes & Films	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
Ceramics & Rubble	1.65	1.65	1.56	1.56	1.56	1.59	1.59	1.59
Wood (lumber)	3.34	3.34	3.95	3.95	3.95	4.58	4.58	2.29
Food Wastes	16.65	16.65	15.88	15.88	15.88	15.49	15.49	7.75
Textiles/leather/rubber	4.42	4.42	4.61	4.61	4.61	4.58	4.58	2.55
Textiles	3.94	3.94	4.09	4.09	4.09	4.06	4.06	2.03
Rubber	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Footwear	0.41	0.41	0.44	0.44	0.44	0.45	0.45	0.45
Yard Wastes	4.03	3.00	4.03	3.06	0.64	4.03	3.06	0.64
Grass & Leaves	3.43	2.40	3.43	2.61	0.34	3.43	2.61	0.34
Brush & Stumps	0.60	0.60	0.60	0.46	0.30	0.60	0.46	0.30
Fines	0.85	0.85	0.80	0.80	0.80	0.81	0.81	0.81
Petrolleum & Chemicals	0.24	0.24	0.23	0.23	0.23	0.23	0.23	0.12
GRAND TOTAL	113.42	100.00	128.18	92.25	61.53	145.10	102.82	51.46
GRAND TOTAL W/O YARD	109.38	97.00	124.15	89.19	60.89	141.07	99.75	50.82

Table 2. Comparison of present and future recycling levels in various jurisdictions.

	PROGRAM ELEMENT EFFICIENCY				
		——BLUE-BOX——			
	B.C. TYPE	MEDIAN			
PARTITIONED CATEGORIES	DEPOSIT LAWS	1991 ONTARIO	USEPA MINIMUM	MAXIMUM	CBNS TYPE INTENSIVE
Paper					
Kraft & Corrugate			48%	90%	90%
Newsprint		68%	48%	90%	90%
Fine Paper			48%	90%	90%
Magazines & Glossy			48%	90%	90%
Books & Phonebooks					25%
Boxboard					25%
Diapers					25%
Mixed Paper			12%	25%	25%
Glass					
Beer Bottles	96%		43%	90%	90%
Softdrink–Refillable	98%		43%	90%	90%
Softdrink–Non-refillable	79%		43%	90%	90%
Liquor & Wine		64%	43%	90%	90%
Containers–Food		45%	43%	90%	90%
Containers–Other					
Flat & Cullet					
Ferrous Metals					
Beer Cans	77%	57%	50%	75%	75%
Softdrink Cans	59%	34%	50%	75%	75%
Food Cans		32%	50%	75%	75%
Other					
Non-ferrous Metals					
Beer Cans	77%	57%	50%	99%	99%
Food Containers & Foil		0%	50%	99%	99%
Manufactured Aluminum			12%	25%	25%
Other Non-ferrous			12%	25%	25%
Plastics					
Container–1(PETE)	83%	61%	48%	99%	99%
Container–2(HDPE)	90%		48%	99%	99%
Container–3(PVC)			24%	50%	50%
Container–4(LDPE)					37%
Container–5(PP)					37%
Container–6(PS)					37%
Container–7(other) & Unidentified					37%
Film & Bags					37%
Housewares					
Toys					
Tapes & Films					
Ceramics & Rubble					
Wood (lumber)					50%
Food Wastes					50%
Textiles/leather/rubber					
Textiles					50%
Rubber					
Footwear					
Yard Wastes					
Grass & Leaves		30%	24%	90%	90%
Brush & Stumps			24%	50%	50%
Fines					
Petroleum & Chemicals					50%

Table 3. Post 3-Rs residue fuel quality.

year	gross generation	low recycling	high recycling	gross generation	low recycling	high recycling	gross generation	low recycling	high recycling
		Discards			Relative Plant Capacity			Total Residue--% of feed	
1990	113.6	100.0		97.5%	100.0%		21.7%	21.6%	
2000	128.4	92.2	61.5	91.0%	94.5%	97.5%	19.1%	19.9%	23.6%
2010	145.4	102.8	51.5	87.8%	90.8%	89.5%	17.4%	18.5%	27.5%
		Higher Heating Value -- Btu/lb			Lower Heating Value -- Btu/lb			%--Carbon	
1990	5,537	5,416		4,876	4,752		30.7	30.1	
2000	5,863	5,688	5,586	5,193	5,006	4,885	32.3	31.2	29.7
2010	6,044	5,878	5,982	5,370	5,194	5,302	33.3	32.2	32.0
		%--Hydrogen			%--Oxygen			%--Nitrogen	
1990	4.18	4.12		24.5	24.4		0.37	0.40	
2000	4.41	4.24	4.07	25.6	23.8	19.4	0.35	0.42	0.52
2010	4.54	4.38	4.42	26.6	24.7	19.7	0.34	0.40	0.04
		%--Sulfur			%--Chlorine			%--Moisture	
1990	0.095	0.098		0.14	0.16		26.0	26.7	
2000	0.097	0.099	0.096	0.16	0.22	0.32	24.8	27.4	30.8
2010	0.099	0.100	0.098	0.17	0.23	0.64	23.9	26.3	25.6
		%--Ash							
1990	14.1	14.0							
2000	12.3	12.7	15.1						
2010	11.1	11.7	17.1						

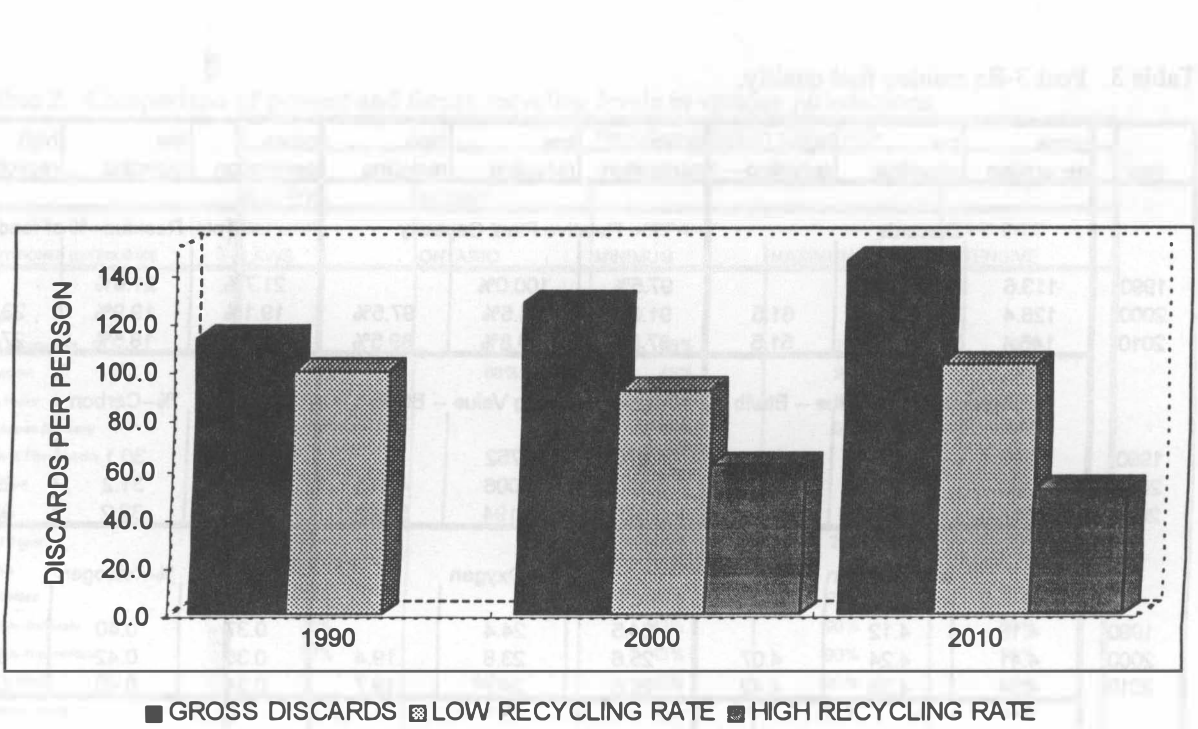

Figure 1. Impact of recycling on discard rate normalized to 100 pounds today.

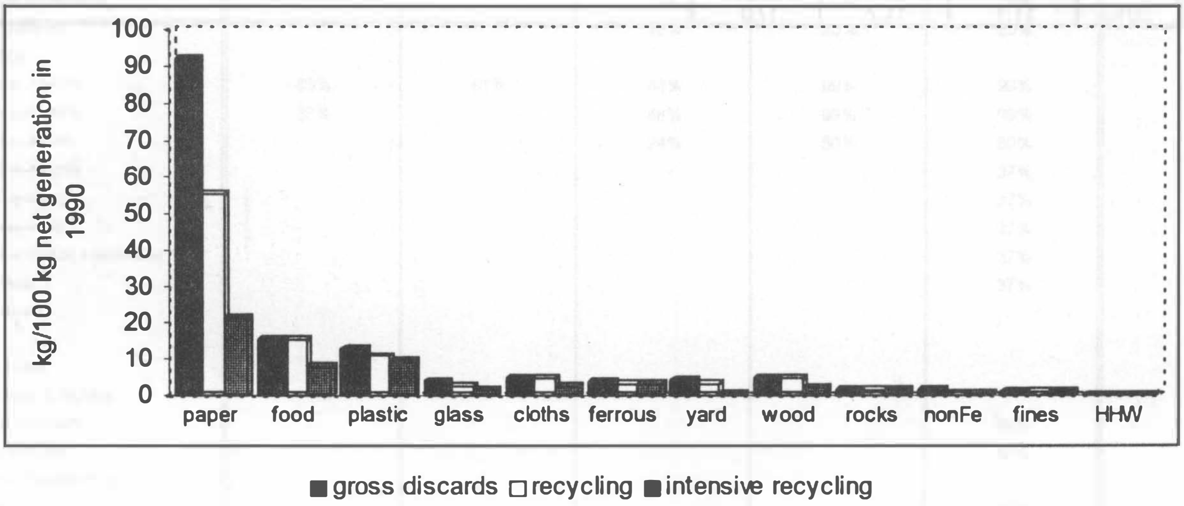

Figure 2. Solid waste composition in 2010 as generated and after 3-Rs.

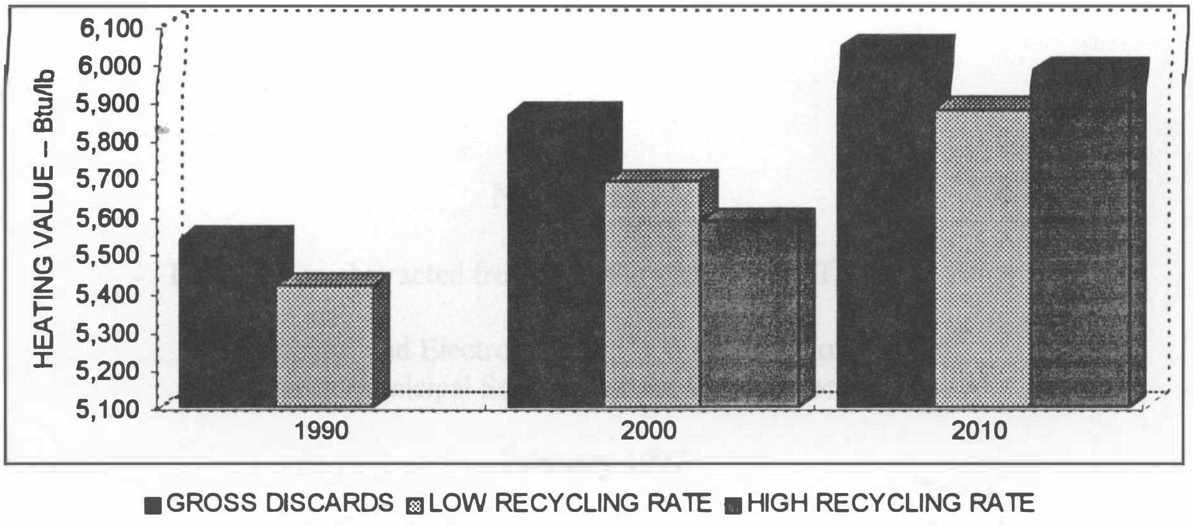

Figure 3. Impact of recycling on heating value.

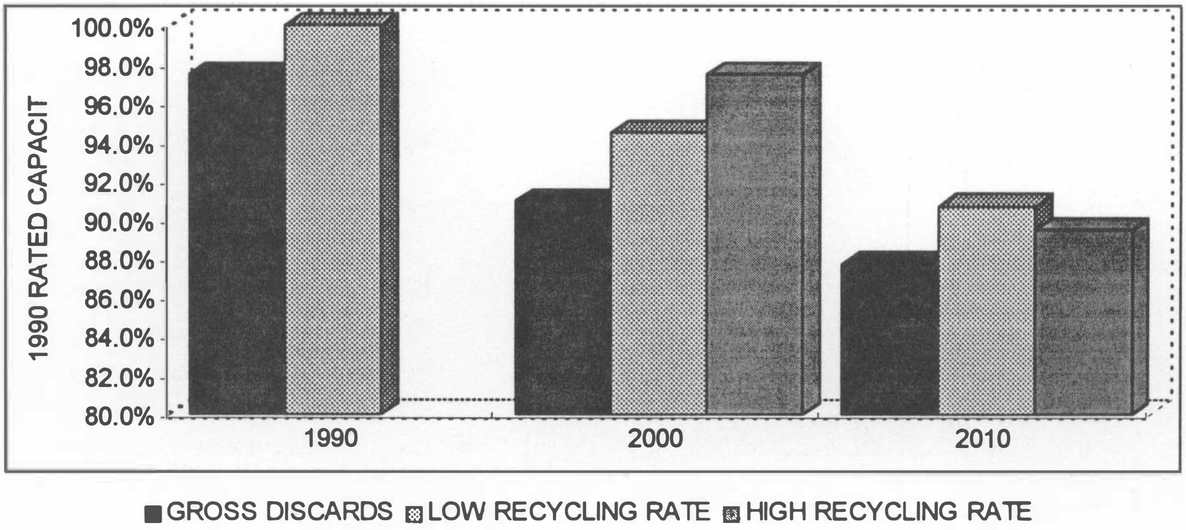

Figure 4. Impact of 3-Rs on EFW capacity normalized to today's new discards.