PERSPECTIVES ON SOLID WASTE MANAGEMENT IN CANADA

AN ASSESSMENT OF THE PHYSICAL, ECONOMIC AND ENERGY DIMENSIONS OF SOLID WASTE MANAGEMENT IN CANADA

VOLUME - I -

2/UP/2/E

Environment Canada — Environnement Canada

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An Assessment of the Physical, Economic and Energy Dimensions of Waste Management in Canada

Volume I of the Perspectives on Solid Waste Management in Canada Series

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Review Notice

This report has been reviewed by members of the Hazardous Waste Branch, Environment Canada and approved for publication. Approval does not necessarily signify that the contents reflect the views and policies of Environment Canada. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

This report is the first of the series "Perspectives on Solid Waste Management in Canada", and was prepared by Resource Integrated Systems Ltd. Each of the reports can serve as a "stand-alone" document, and also as part of the integrated study. The complete set of reports is available through Environment Canada.

Abstract

This report quantifies the amount and composition of waste generated, diverted, and disposed of in Canada in 1992. It also estimates the costs and employment associated with the waste management system in place in Canada at that time. Finally, it estimates the amount of energy expended on and recovered from solid waste management activities in Canada in 1992.

These estimates were intended to identify target areas for waste diversion efforts and potential opportunities for research and commercialization of alternative technologies to handle waste. The methodology applied is appropriate for the broad perspective of this project. However, these estimates are based on data available from published sources and were not intended to represent detailed, comprehensive estimates of each waste stream and material category.

Résumé

Ce rapport fournit des données sur la quantité et la composition des déchets produits, valorisés et éliminés au Canada en 1992. Il offre aussi une estimation des coûts et du nombre d'emplois liés au système de gestion des déchets en place au Canada cette année-là. Enfin, on y estime la quantité d'énergie consommée et la quantité d'énergie produite par les activités de gestion des déchets solides au Canada en 1992.

Ces estimations visent à définir des secteurs clés pour les efforts de valorisation des déchets ainsi que des possibilités pour la recherche et la commercialisation de technologies de remplacement pour la manutention des déchets. La méthode appliquée convient à la vaste envergure de l'étude. Toutefois, les estimations sont fondées sur les données disponibles dans les sources publiées et elles ne visaient pas à donner une évaluation détaillée et complète de chaque flux de déchets et de chaque catégorie de matières.

Foreword

The series "Perspectives on Solid Waste Management in Canada" *is a study of effective systems and technologies to collect, handle, and process nonhazardous waste in Canada. The focus of the study is on alternatives to landfill - i.e., emerging and developed systems and technologies to help achieve Canada's goal [as established through the Canadian Council of Ministers of the Environment (CCME)] of 50% diversion of waste from disposal by the year 2000.*

Environment Canada was the lead agency for this project. The Steering Committee included representation from: Industry Canada; Natural Resources Canada (Forestry and Energy Departments); Federation of Canadian Municipalities; National Research Council; Ontario Waste Management Association, and the Ontario Ministry of the Environment and Energy. In addition, the project was supported through the input of four advisory groups, representing over 50 experts from across the country with specific expertise in key project areas.

The series "Perspectives on Solid Waste Management in Canada" *contains three volumes:*

- *Volume I - Assessment of the Physical, Economic, and Energy Dimensions of Solid Waste Management in Canada;*
- *Volume II - Options for Integrated Municipal Solid Waste Diversion; and*
- *Volume III - Case Studies of "Leading-edge" Solid Waste Diversion Projects.*

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Section 1

Introduction

1.1 Background

The Perspectives on Solid Waste Management in Canada project is a study of effective systems and technologies to collect, handle and process non-hazardous solid waste in Canada. The study focuses on alternatives to landfill, i.e., emerging and developed systems and technologies to help achieve Canada's goal (as established through the Canadian Council of Ministers of the Environment [CCME]) of 50% diversion of waste from disposal by the year 2000.

Environment Canada was the lead agency for the project. The project steering committee included representatives from: Industry Canada; Natural Resources Canada (Forestry and Energy Department); Federation of Canadian Municipalities; National Research Council; Ontario Waste Management Association and the Ontario Ministry of Environment and Energy. The project was also supported through the input of four technical advisory groups, representing over 50 experts from across the country.

The project contains three reports:

- Volume I - Assessment of the Physical, Economic and Energy Dimensions of Solid Waste Management in Canada;
- Volume II - Options for Integrated Municipal Solid Waste Diversion; and
- Volume III - Case Studies of Leading-edge Solid Waste Diversion Projects in Canada (including selected U.S. and European projects).

The first report, *Assessment of the Physical, Economic and Energy Dimensions of Solid Waste Management in Canada*,was prepared by Resource Integration Systems Ltd., with the assistance of BOVAR Concord Environmental.

Each of the reports for this project is intended to serve as a "stand-alone" document, and also as part of the integrated study.

1.2 Objectives

This report:

- quantifies the amount and composition of waste generated, diverted, and disposed of in Canada in 1992;
- estimates the costs and employment associated with the waste management system in place in Canada in 1992; and
- estimates the amount of energy expended on and recovered from solid waste management activities in Canada in 1992.

These estimates were intended to be used in the project to identify target areas for waste diversion efforts and potential opportunities for research and commercialization of alternative technologies to handle waste. The methodology applied is appropriate for the broad perspective of this project. However, these estimates are based on data available from published sources and are not intended to represent detailed, comprehensive estimates of each waste stream and material category.

1.3 Report Structure

The waste quantity and composition estimates are presented in Section 2, with detailed provincial descriptions provided in Appendix A. Cost and employment estimates are in Section 3 and detailed calculations are in Appendix B. Energy related estimates are presented in Section 4. A detailed description of how the energy estimates were developed is in Appendix C. A series of tables with energy estimates at a provincial level is in Appendix D.

Section 2

Solid Waste Quantity and Composition Estimates

2.1 Introduction

This section develops estimates, based on available data, of the overall flow of solid, non-hazardous waste in Canada in 1992 by material, generating source, and management method. There is also a brief description of the approach used to develop the estimates.

These estimates identify target areas for waste diversion efforts and potential opportunities for research and commercialization of alternative technologies to handle waste. The methodology applied is appropriate for the broad perspective of this project. These estimates are based on data from published sources and are not intended to represent detailed, comprehensive estimates of each waste stream and material category. Therefore, these estimates might differ from those developed using different methodologies.

Together with the findings from the other reports in this series, these estimates outline key issues in the formulation of a research and development and commercialization strategy for waste management technology in Canada.

2.2 Methodology

2.2.1 Information Sources Used

Estimates on the quantities of materials generated, diverted, and disposed of in each province/territory in 1992 were based primarily on information provided to Environment Canada by provincial agencies for the CCME National Solid Waste Inventory (NSWI). Additional sources of data were used to break the provincial estimates down to a greater level of detail. These included waste composition studies carried out in various Canadian communities and neighbouring regions or provinces, where the waste composition was similar. A list of the waste composition studies is in the references at the end of this section.

Additional information on specific issues (such as the amount of waste incinerated nationally) was obtained from a number of Environment Canada reports and in-house files.

For the most part, material categories in the National Solid Waste Tracking System were used for the waste composition estimates. Some categories were omitted if they were not considered relevant to this study. Some material categories (such as auto wrecks, and road and bridge construction waste) have been included in this analysis, even though these are not typically considered part of the municipal solid waste stream (they are not typically disposed of in municipal landfills).

For some components of the waste stream (such as construction and demolition waste and white goods), estimates of generation and diversion were taken primarily from published reports which estimated national quantities. The reports used for the estimates are listed in the references at the end of this section.

The approach used to estimate the quantity and composition of waste managed in each province varied, because of the quality of existing data and the sources which were considered most appropriate for extrapolations. The approach is described in more detail for each province in appendix A.

2.2.2 Developing Waste Quantity and Composition Estimates

Estimates of the quantities of solid waste generated, diverted, combusted, and landfilled from the residential, the institutional, the commercial and the industrial (IC&I) and the construction and the demolition (C&D) sectors have been developed. The definition for these terms is in line with the concepts used in the National Solid Waste Tracking System. Specific definitions are in appendix A.

The following waste flow estimates were developed:

- Estimates of the quantity and composition of waste generated, diverted, combusted and disposed of were developed for each province/territory using a variety of sources and methods. The provincial/territorial estimates were combined to develop national estimates for Canada.
- Depending on the data available, either waste generation or waste disposal data were used as the starting point for provincial waste quantity estimates.
- Where waste generation data were used, data on waste recycled, composted and incinerated were subtracted from generated values in order to estimate the waste disposed of.
- Where waste disposal data were used as the starting point of the estimates, data on waste recycled, composted and incinerated were added to disposed of values in order to estimate the waste generated.
- Data on waste recycled, composted, and incinerated were obtained from provincial sources, Environment Canada, and published and unpublished reports. Where information was not available at the detailed composition level required for the analysis, a number of assumptions were used to develop a preliminary estimate of the parameter required. These assumptions can be refined in future estimates when better data become available.
- When the quantities of waste managed by each method were identified, the quantities were separated into three major generating sources: residential, IC&I and C&D.
- Available waste composition studies were used to estimate the quantities of different materials in each waste stream (residential, IC&I and C&D).

2.3 National Solid Waste Quantity and Composition Estimates

Other waste generation estimates may differ from those presented in this report. The various estimates in other reports and published data are based on different approaches, sources, and methodologies, and yield different results. Differing composition estimates have some effect on estimates of energy content of waste but do not significantly affect economic analyses.

Estimates of the quantity and composition of waste generated, diverted, combusted, and landfilled were developed for each province/territory using a variety of sources and methods. The provincial/territorial estimates were combined to develop national estimates for Canada, and are examined in this section. Individual provincial/territorial estimates are examined in section 2.4. Detailed provincial/territorial estimates are in appendix A.

Estimates of the quantities of waste generated, diverted, combusted and landfilled in Canada in 1992 by generating sector (residential, IC&I, and C&D), and by major material category (paper, glass, metals, plastic, organics, inorganics and other) are presented in table 2.1. The data for the total waste stream by material are summarized in table 2.2.

2.3.1 Solid Waste Generation in Canada in 1992

Approximately 33.2 million tonnes of solid waste was generated in Canada in 1992. Based on a population of almost 27 million in 1992, this translates to an overall generation rate of 1.23 tonnes/capita/year (t/cap/yr). This per-capita waste generation rate is reduced to 0.82 t/cap/yr when auto hulks and C&D waste are not included in the estimate. The per-capita landfill rate is 0.82 t/cap/yr, which is reduced to 0.65 t/

Table 2.1 Waste quantities generated, diverted, combusted and landfilled by generating sector and material in Canada 1992

Waste Materials	Generated (tonnes)				Diverted (tonnes)				Sent for Combustion (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)			
	Res	IC&I	C&D	Total	Res	IC&I	C&D	Total	Total	Total	Res	IC&I	C&D	Total
Paper	3,530,000	4,730,000	231,000	8,490,000	484,000	1,250,000	51,500	1,780,000	403,000		2,760,000	3,370,000	179,000	6,300,000
Glass	524,000	444,000	2,000	970,000	156,000	78,700		235,000	52,400		326,000	355,000	2,000	682,000
Metals	690,000	2,990,000	254,000	3,940,000	211,000	2,010,000	86,700	2,310,000	65,700		446,000	945,000	168,000	1,560,000
Plastic	641,000	1,110,000	2,680	1,760,000	12,600	57,000		69,600	100,000		564,000	1,020,000	2,680	1,590,000
Organics	3,920,000	2,360,000	1,440,000	7,730,000	316,000	97,400	385,000	798,000	395,000		3,290,000	2,190,000	1,060,000	6,540,000
Inorganics	125,000	80,200	7,890,000	8,090,000	312	68,200	4,910,000	4,980,000	12,500	341,000	372,000	93,900	2,980,000	3,440,000
Other	1,110,000	936,000	153,000	2,200,000	4,310	76,400	11	80,800	168,000		967,000	834,000	153,000	1,950,000
Total	10,500,000	12,700,000	9,980,000	33,200,000	1,180,000	3,640,000	5,430,000	10,200,000	1,200,000	341,000	8,720,000	8,800,000	4,540,000	22,100,000

Table 2.2 Waste quantities generated, diverted, combusted and landfilled by material in Canada 1992

Waste Materials	Generated (tonnes)	Recycled (tonnes)	Backyard Composting (tonnes)	Central Composting (tonnes)	Sent For Combustion EFW Feed (tonnes)	Sent For Combustion non-EFW Feed (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)
	Total	Total	Res	Total	Total	Total	Total	Total
Paper	8,490,000	1,780,000	0	0	364,000	39,400		6,300,000
Glass	970,000	235,000	0	0	46,000	6,380		682,000
Metals	3,940,000	2,310,000	0	0	59,300	6,380		1,560,000
Plastic	1,760,000	69,600	0	0	90,900	9,180		1,590,000
Organics	7,730,000	385,000	98,200	315,000	363,000	32,500		6,540,000
Inorganics	8,090,000	4,980,000	0	0	11,200	1,340	341,000	3,440,000
Other	2,200,000	80,800	0	0	153,000	15,800		1,950,000
Total	33,200,000	9,840,000	98,200	315,000	1,090,000	111,000	341,000	22,062,000

Population = 27,000,000
Per-capita Generation (tonnes/cap.) = 1.23
Per-capita Diversion (tonnes/cap.) = 0.38
Per-capita Incineration (incl. ash/res.) (tonnes/cap.) = 0.04
Per-capita Landfilled (incl. ash/res.) (tonnes/cap.) = 0.82

Notes:

1. For individual material categories, the quantities landfilled, combusted, composted and recycled may not equal the quantities generated. This is because the ash/residue generated during combustion appears in the inorganic category, and it appears both in Ash/Residue and Landfilled columns.
2. All figures have been rounded to three significant digits.
3. The approach used to develop these estimates was adopted to meet the broad perspective of this project. Refer to Section 2.1, paragraph 2 for additional information on the approach used.

cap/yr if C&D waste is excluded from the analysis.

Of the total solid waste generated in Canada in 1992, approximately:

- 10.5 million tonnes (32%) was from residential sources,
- 12.7 million tonnes (38%) was from IC&I sources, and
- 10.0 million tonnes (30%) was generated by C&D activities.

The amount of waste generated in each sector is shown in figure 2.1.

2.3.2 *Composition of Solid Waste Generated in Canada in 1992*

The waste stream generated in Canada in 1992 is estimated to have included the following materials:

- 8.5 million tonnes of paper (26%);
- 8.1 million tonnes of inorganics (24%), of which the majority was asphalt (3.2 million tonnes), and concrete (2.0 million tonnes);
- 7.7 million tonnes of organics (including wood) (23%)
- 3.9 million tonnes of metal (12%), of which an estimated 1.1 million tonnes are auto hulks;
- 2.2 million tonnes of other waste (7%);
- 1.8 million tonnes of plastic (5%); and
- 1 million tonnes of glass (3%).

The estimated composition of the generated waste stream is shown in figure 2.2.

2.3.3 *Solid Waste Management in Canada in 1992*

The estimated 33.2 million tonnes of solid waste generated in Canada in 1992 were managed by the following methods:

- 21.7 million tonnes (65.5%) were landfilled (not including ash/residue generated during combustion);
- 9.8 million tonnes (29.7 %) were recycled;
- 1.1 million tonnes (3.3%) were sent for combustion with energy recovery;
- 315,000 tonnes (0.9%) were diverted through central composting;
- 111,000 tonnes (0.3%) were sent for combustion without energy recovery; and

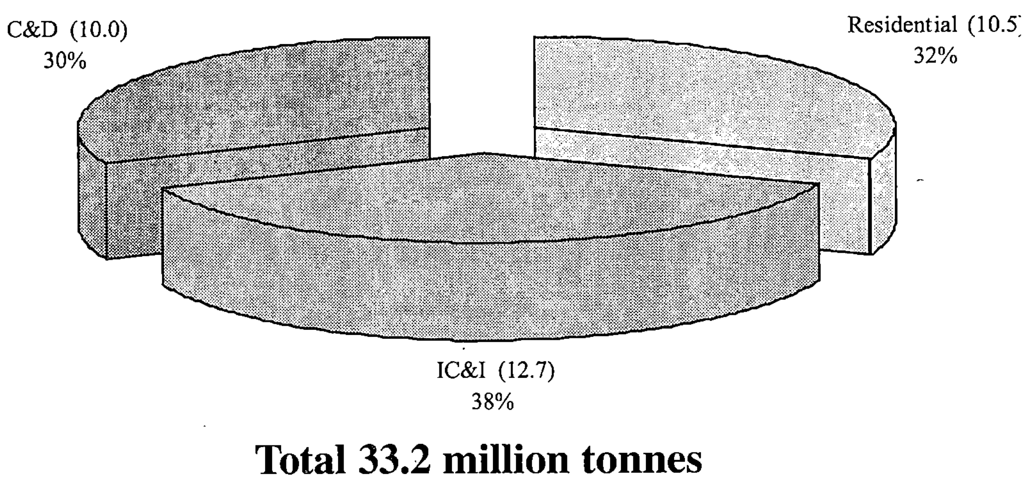

Figure 2.1 Source of solid waste generated in Canada, 1992 (million tonnes)

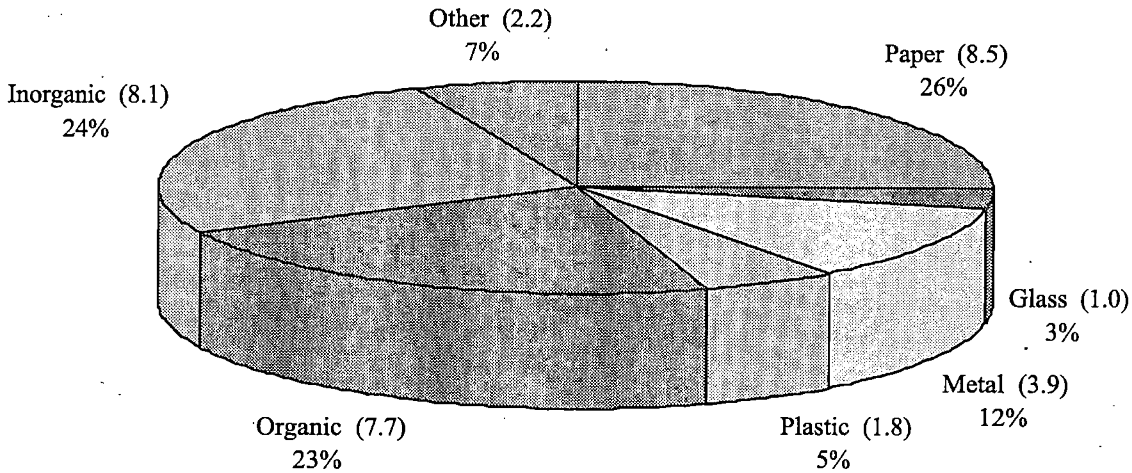

Figure 2.2 Composition of solid waste generated in Canada, 1992 (million tonnes)

- 98,000 tonnes (0.3%) were diverted through backyard composters.

Approximately 1.2 million tonnes of waste (3.6% of the waste stream) was sent for combustion, but approximately 341,000 tonnes of this total was converted to ash/residue and eventually landfilled. Therefore, for the purpose of this study, approximately 860,000 tonnes was considered gasified during combustion in 1992.

The various waste handling methods are shown in figure 2.3.

2.3.4 Solid Waste Diversion in Canada in 1992

Approximately 31% of the waste stream was diverted from disposal in 1992 through either recycling or composting. The diverted waste stream is estimated to contain:

- 5.0 million tonnes of inorganics, of which the majority was asphalt (2.6 million tonnes), and concrete (1.6 million tonnes);
- 2.3 million tonnes of metal, of which an estimated 1.1 million tonnes was auto hulks;
- 1.8 million tonnes of paper;
- 798,000 tonnes of organics (248,000 tonnes of leaf and yard waste, and 474,000 tonnes of wood);
- 235,000 tonnes of glass;
- 70,000 tonnes of plastic; and
- 81,000 tonnes of miscellaneous waste.

A breakdown of the diverted waste stream composition by material is presented in figure 2.4.

2.3.5 Solid Waste Combustion and Landfilling in Canada in 1992

An estimated 22.1 million tonnes of solid waste was landfilled in Canada in 1992. Approximately 341,000 tonnes of this total was ash/residue produced from the combustion of approximately 1.2 million tonnes of waste. The combined combusted and landfilled waste stream is estimated to have consisted of:

- 30% (6.9 million tonnes) organics;
- 29% (6.7 million tonnes) paper;
- 14% (3.1 million tonnes) inorganics (not including ash/residue from combustion);

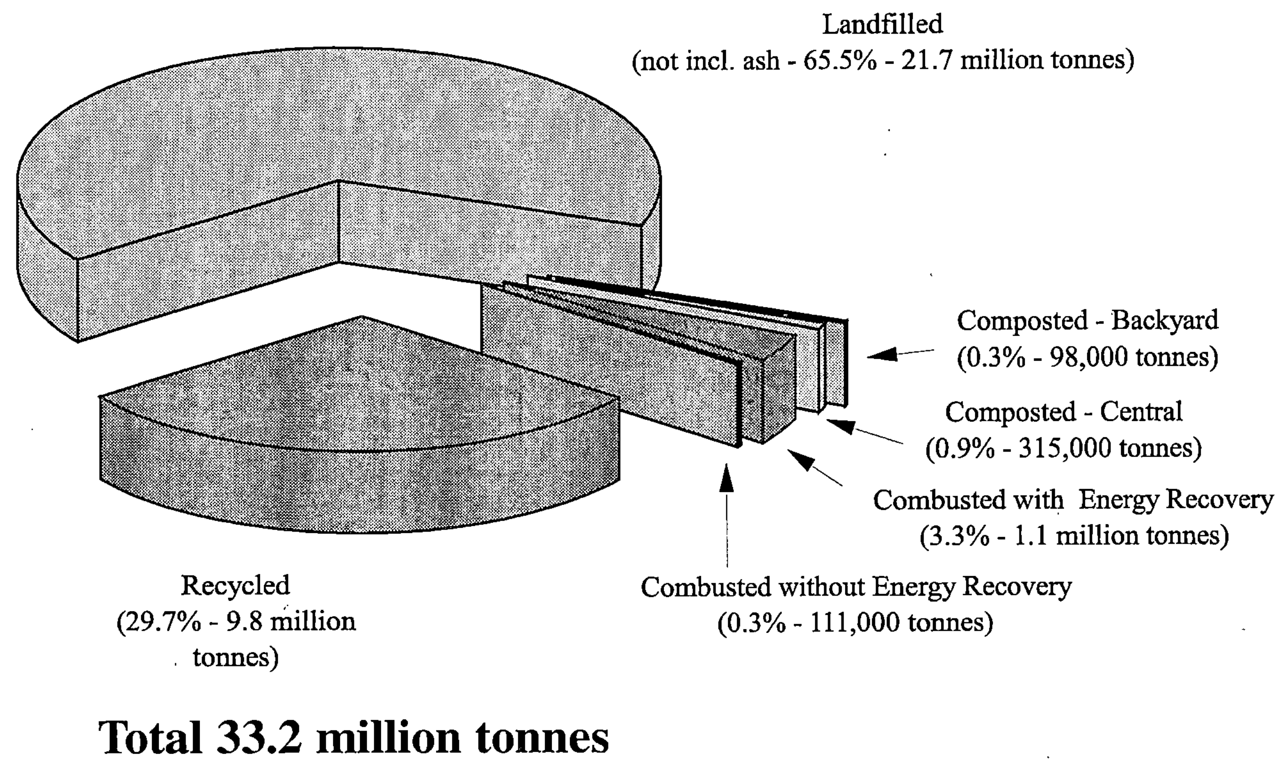

Figure 2.3 Percentage of solid waste managed by each method in Canada, 1992

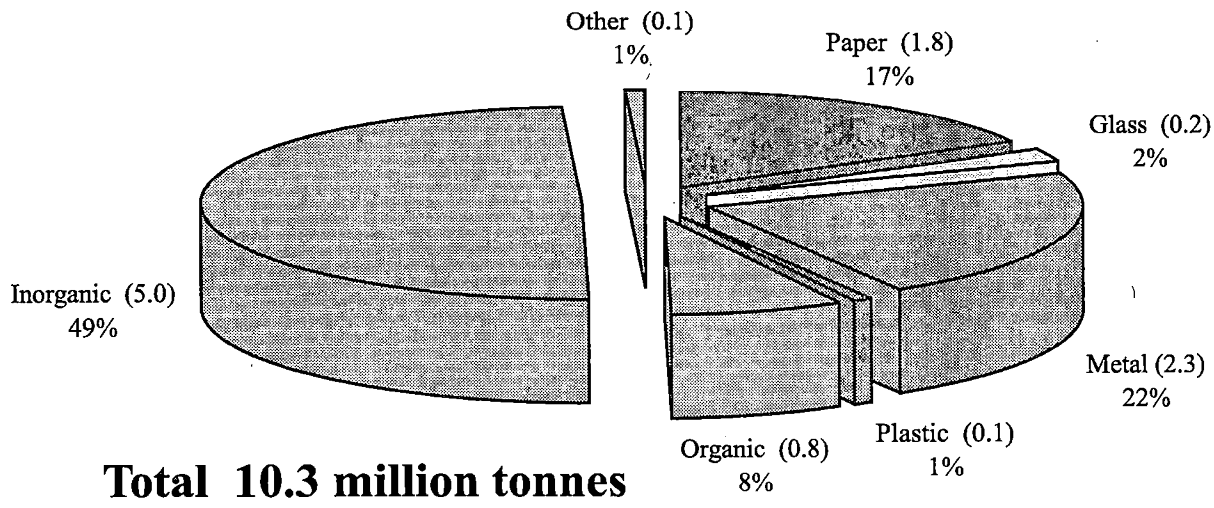

Figure 2.4 Composition of solid waste diverted in Canada, 1992 (million tonnes)

- 8% (1.7 million tonnes) plastic;
- 7% (1.6 million tonnes) metal;
- 3% (0.7 million tonnes) glass; and
- 9% (2.1 million tonnes) miscellaneous wastes.

The composition of the combined combusted and landfilled waste stream is presented in figure 2.5.

2.3.6 Solid Waste Diversion by Generating Sector in 1992

An estimated 10.2 million tonnes of waste was diverted in Canada in 1992. The sources of the diverted wastes (see figure 2.6) were:

- 5.4 million tonnes from C&D activities;
- 3.6 million tonnes from IC&I sources; and
- 1.2 million tonnes from residential sources.

Diversion rates (diverted total expressed as a percentage of the generated total) for each of the major waste generating sources were:

- 54% for C&D waste;
- 29% for IC&I waste; and
- 11% for residential waste.

2.3.7 Solid Waste Combusted and Landfilled by Generating Source

An estimated 22.9 million tonnes of waste was either sent for combustion or landfilling in Canada in 1992 (23.3 million tonnes if the ash/residue from combustion is included in the quantity sent for landfilling). The sources of this waste (see figure 2.7) were:

- 9.4 million tonnes (41%) from residential sources;
- 9.0 million tonnes (39%) was from IC&I sources; and
- 4.5 million tonnes (20%) was from C&D activities.

2.4 Provincial Solid Waste Quantity and Composition Estimates

The national waste quantity and composition estimates presented in the previous sections were derived from separate quantity and composition estimates developed for each province and territory in Canada in 1992. The method by which each provincial estimate was developed varied, depending on the amount of information available on the provincial or territorial waste management system, and the level of detail at which material-specific information was maintained. The provincial estimates are examined in more detail in appendix A.

Provincial/territorial estimates are provided in tables 2.3 to 2.26. Two summary tables are presented for each province/territory. Estimates of the quantities of waste generated, diverted, combusted, and landfilled in the province or territory in 1992 by generating sector (residential, IC&I and C&D), and by major material category (paper, glass, metal, plastic, organics, inorganics and other) are in the first table. The provincial/territorial data for the total waste stream by material is in the second table. It also includes provincial/territorial population data, and calculated generation, diversion, combustion and landfill rates in tonnes/capita/year.

2.5 Observations on National Solid Waste Quantity and Composition Analysis

The waste quantity and composition analysis provided valuable information on the current flow of materials in Canada. This helped identify waste streams that should be targeted for increased diversion if the 50% diversion target is to be achieved. Where current diversion options are limited for these materials, the results of the analysis were used in conjunction with the results of the case studies to identify research and development needs in the solid waste diversion

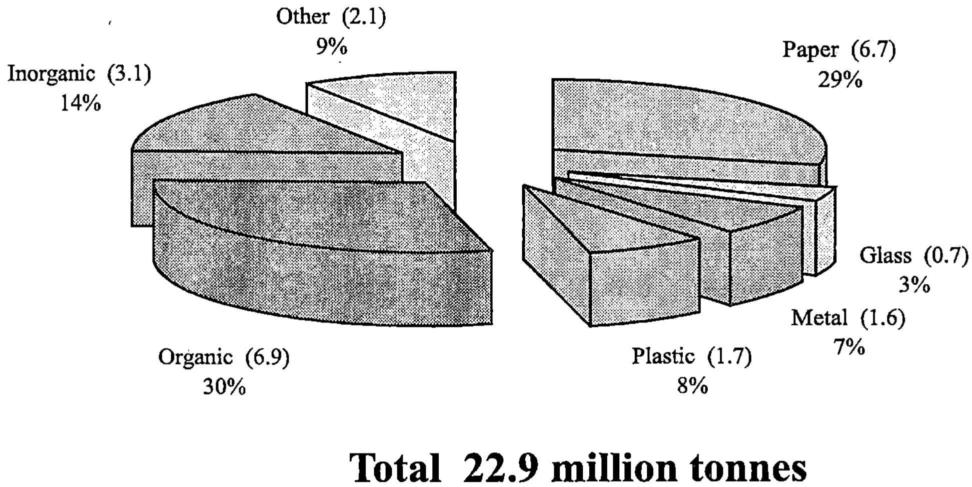

Figure 2.5 Composition of solid waste landfilled and combusted in Canada, 1992 (million tonnes)

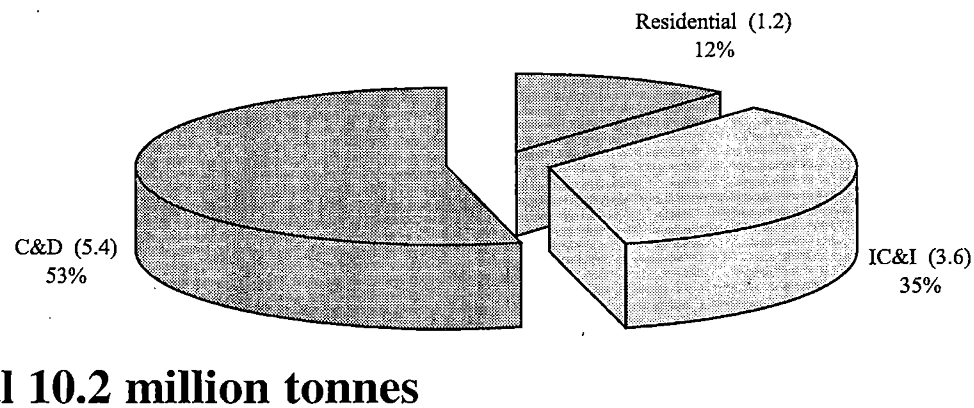

Figure 2.6 Source of solid waste diverted in Canada, 1992 (million tonnes)

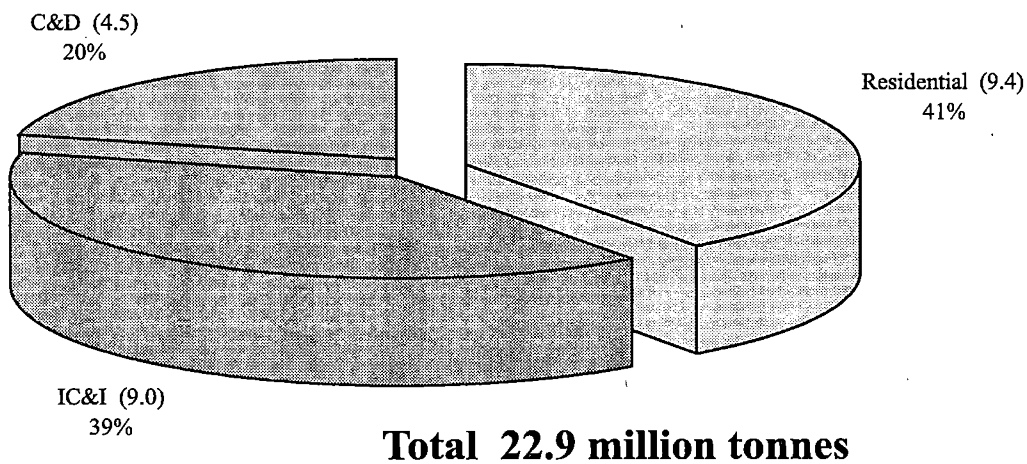

Figure 2.7 Source of solid waste landfilled and combusted in Canada, 1992 (million tonnes)

area. Significant observations from the analysis are:

- Organics and paper together make up 12.8 million tonnes, or almost 58% of the landfilled waste stream. Note that the amounts of paper and organics combusted are not considered in this conclusion. To achieve 50% diversion, significant effort needs to be directed at diverting these two streams.
- The residential sector landfilled 2.8 million tonnes of paper in 1992, and the IC&I sector disposed of 3.4 million tonnes. Paper diversion efforts need to focus on both sectors.
- The residential sector disposed of 3.3 million tonnes of organics in 1992 (2 million tonnes of food and 1 million tonnes of yard waste). Most of the increased diversion activities should be directed to diverting food waste from residential sources.
- The IC&I sector disposed of 2.2 million tonnes of organics in 1992. Most of this total was food (1.1 million tonnes) or wood (600,000 tonnes). Diversion efforts need to focus on food and wood from IC&I sources.
- The C&D sector disposed of 1 million tonnes of wood in 1992. Increased diversion efforts should be directed at this waste stream.
- The C&D sector disposed of 3 million tonnes of inorganics in 1992 (597,000 tonnes asphalt and 432,000 tonnes concrete). Efforts to divert these waste streams should be increased.

2.6 Conclusions Regarding Achievement of 50% Diversion Target

The CCME goal of 50% reduction by the year 2000 refers to a reduction in per capita disposal and is measured against a 1988 baseline. The following discussion uses the estimates for 1992 developed in this section to illustrate the challenge ahead in meeting the 50% diversion target. Specific components of the waste stream are discussed as well as the required diversion to be achieved by the year 2000 using available 1992 data.

Based on 1992 data, an additional 6.5 to 11 million tonnes of waste must be diverted to meet the CCME target by the year 2000. This can be achieved by targetting a limited number of waste streams for a concerted diversion effort. To achieve 50% diversion of waste from disposal by the year 2000, the following efforts should be undertaken:

- increased diversion of paper from both the residential and IC&I sectors (this accounted for 6.6 million tonnes sent for disposal in 1992);
- increased diversion of food and yard waste from the residential waste stream (this accounted for 3.3 million tonnes disposed of in 1992);
- increased diversion of asphalt, concrete and wood from the C&D waste stream (this currently accounts for 2.0 million tonnes disposed of);
- increased diversion of food and wood from the IC&I waste stream (this accounted for 1.7 million tonnes disposed of in 1992).

The paper, food, yard waste, wood, asphalt and concrete waste streams account for 13.8 million tonnes of the waste stream disposed of in 1992. Diverting between 6.5 and 11 million tonnes, or slightly more than half (using the mid-range) of the above waste stream totals would meet the 50% diversion target.

2.7 References

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Table 2.3 Waste quantities British Columbia, 1992

Waste Materials	Generated (tonnes)				Diverted (tonnes)				Sent for Combustion (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)			
	Residential	IC&I	C&D	Total	Residential	IC&I	C&D	Total	Total	Total	Residential	IC&I	C&D	Total
Paper	480,000	575,000	2,430	1,060,000	80,000	208,000		288,000	92,200		342,000	331,000	2,430	676,000
Glass	49,400	63,000	810	113,000	18,200	29,000		47,200	7,710		26,800	30,700	810	58,300
Metals	36,800	150,000	14,400	202,000	1,900	73,000	5,450	80,300	10,600		31,600	70,100	8,910	111,000
Plastic	90,500	122,000	1,620	214,000	241	8,480		87,200	23,700		77,300	102,000	1,620	181,000
Organics	268,000	347,000	302,000	917,000	41,400			41,400	65,600		194,000	314,000	302,000	810,000
Inorganics	49,200	68,200	863,000	980,000	312	68,200	503,000	571,000	6,980	59,200	78,800	22,400	360,000	461,000
Other	294,000	115,000	134,000	543,000	226	25,000	11	25,300	50,600		252,000	81,400	134,000	467,000
Total	1,270,000	1,440,000	1,320,000	4,020,000	142,000	412,000	508,000	1,060,000	258,000	59,200	1,000,000	952,000	810,000	2,760,000

Table 2.4 Waste quantities generated, diverted, combusted and landfilled by material in British Columbia

Waste Materials	Generated (tonnes)	Recycled (tonnes)	Backyard Composting (tonnes)	Central Composting (tonnes)	Sent For Combustion EFW Feed (tonnes)	Sent For Combustion non-EFW Feed (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)
	Total	Total	Res.	Total	Total	Total	Total	Total
Paper	1,060,000	288,000			84,100	8,070		676,000
Glass	113,000	47,200			7,060	653		58,300
Metals	202,000	80,300			9,950	705		111,000
Plastic	214,000	8,720			21,800	1,950		181,000
Organics	917,000	0	5,780	35,600	60,400	5,180		810,000
Inorganics	980,000	571,000			6,190	790	59,200	461,000
Other	543,000	25,300			45,500	5,150		467,000
Total	4,020,000	1,020,000	5,780	35,600	235,000	22,500	59,200	2,760,000

Population = 3,370,000
Per-capita generation (tonnes/cap.) = 1.19
Per-capita diversion (tonnes/cap.) = 0.31
Per-capita combustion (incl. ash/res.) (tonnes/cap.) = 0.08
Per-capita landfilled (incl. ash/res.) (tonnes/cap.) = 0.82

Notes:
1. For individual material categories, the quantities landfilled, combusted, composted and recycled may not equal the quantities generated. This is because the ash/residue generated during combustion appears in the Inorganic category, and it appears both in Ash/Residue as well as Landfilled columns.
2. All figures have been rounded to three significant digits.
3. The approach used to develop these estimates was adopted to meet the broad perspective of this project. Refer to section 2.1, paragraph 2 for additional information on the approach used.

Table 2.5 Waste quantities Yukon Territory, 1992

Waste Materials	Generated (tonnes)				Diverted (tonnes)				Sent for Combustion (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)			
	Residential	IC&I	C&D	Total	Residential	IC&I	C&D	Total	Total	Total	Residential	IC&I	C&D	Total
Paper	1,090	1,390	806	3,280	38	99		137			1,050	1,290	806	3,150
Glass	243	245		488	152	152		304			91	93		184
Metals	273	1,610	806	2,690	22	1,060		1,080			251	551	806	1,610
Plastic	212	438		650	2	2		3			211	436		647
Organics	758	1,730	3,520	6,010	25	25	458	535			733	1,700	3,040	5,480
Inorganics			10,100	10,100			5,170	5,170					4,940	4,940
Other	455	724		1,180							455	724		1,180
Total	3,030	6,130	15,200	24,400	238	1,340	5,650	7,220			2,790	4,800	9,590	17,200

Table 2.6 Waste quantities generated, diverted, combusted and landfilled by material in Yukon Territory

Waste Materials	Generated (tonnes)	Recycled (tonnes)	Backyard Composting (tonnes)	Central Composting (tonnes)	Sent For Combustion EFW Feed (tonnes)	Sent For Combustion non-EFW Feed (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)
	Total	Total	Res.	Total	Total	Total	Total	Total
Paper	3,280	137						3,150
Glass	488	304						184
Metals	2,690	1,080						1,610
Plastic	650	3						647
Organics	6,010	485		50				5,480
Inorganics	10,100	5,170						4,940
Other	1,180							1,180
Total	24,400	7,180	0	50				17,200

Population = 28,000
Per-capita generation (tonnes/cap.) = 0.87
Per-capita diversion (tonnes/cap.) = 0.26
Per-capita incineration (incl. ash/res.) (tonnes/cap.) = 0.00
Per-capitalLandfilled (incl. ash/res.) (tonnes/cap.) = 0.61

Notes:
1. For individual material categories, the quantities landfilled, combusted, composted and recycled may not equal the quantities generated. This is because the ash/residue generated during combustion appears in the Inorganic category, and it appears both in Ash/Residue as well as Landfilled columns.
2. All figures have been rounded to three significant digits.
3. The approach used to develop these estimates was adopted to meet the broad perspective of this project. Refer to section 2.1, paragraph 2 for additional information on the approach used.

Table 2.7 Waste quantities Alberta, 1992

Waste Materials	Generated (tonnes)				Diverted (tonnes)				Sent for Combustion (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)			
	Residential	IC&I	C&D	Total	Residential	IC&I	C&D	Total	Total	Total	Residential	IC&I	C&D	Total
Paper	229,000	534,000	47,600	810,000	14,700	1,820		16,600			214,000	532,000	47,600	794,000
Glass	9,800	49,300		59,100	726			726			9,080	49,300		58,400
Metals	35,600	261,000	47,600	345,000	1,920	149,000		151,000			33,700	113,000	47,600	194,000
Plastic	60,700	164,000		225,000	208			208			60,500	164,000		225,000
Organics	299,000	334,000	208,000	841,000	16,000	706	28,100	44,800			283,000	334,000	180,000	796,000
Inorganics	4,840		614,000	618,000			350,000	350,000			4,840		264,000	268,000
Other	15,700	131,000		146,000		2		2			15,700	131,000		146,000
Total	654,000	1,470,000	917,000	3,040,000	33,600	151,000	378,000	563,000			621,000	1,320,000	539,000	2,480,000

Table 2.8 Waste quantities generated, diverted, combusted and landfilled by material in Alberta

Waste Materials	Generated (tonnes)	Recycled (tonnes)	Backyard Composting (tonnes)	Central Composting (tonnes)	Sent For Combustion EFW Feed (tonnes)	Sent For Combustion non-EFW Feed (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)
	Total	Total	Res.	Total	Total	Total	Total	Total
Paper	810,000	16,600						794,000
Glass	59,100	726						58,400
Metals	345,000	151,000						194,000
Plastic	225,000	208						225,000
Organics	841,000	28,100		16,700				796,000
Inorganics	618,000	350,000						268,000
Other	146,000	2						146,000
Total	3,040,000	546,000		16,700				2,480,000

Population = 2,560,000
Per-capita generation (tonnes/cap.) = 1.19
Per-capita diversion (tonnes/cap.) = 0.22
Per-capita incineration (incl. ash/res.) (tonnes/cap.) = 0.00
Per-capita landfilled (incl. ash/res.) (tonnes/cap.) = 0.97

Notes:

1. For individual material categories, the quantities landfilled, combusted, composted and recycled may not equal the quantities generated. This is because the ash/residue generated during combustion appears in the Inorganic category, and it appears both in Ash/Residue as well as Landfilled columns.
2. All figures have been rounded to three significant digits.
3. The approach used to develop these estimates was adopted to meet the broad perspective of this project. Refer to section 2.1, paragraph 2 for additional information on the approach used.

Table 2.9 Waste quantities Saskatchewan, 1992

Waste Materials	Generated (tonnes)				Diverted (tonnes)				Sent for Combustion (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)			
	Residential	IC&I	C&D	Total	Residential	IC&I	C&D	Total	Total	Total	Residential	IC&I	C&D	Total
Paper	122,000	162,000	8,650	293,000	15,000	15,000		30,000			108,000	147,000	8,650	263,000
Glass	18,400	27,500		45,900	3,900	3,900		7,800			14,500	23,600		38,100
Metals	42,700	83,900	8,650	135,000	1,200	58,800		60,000			41,500	25,100	8,650	75,200
Plastic	9,080	30,300		39,400	800	800		1,600			8,280	29,500		37,800
Organics	243,000	94,600	37,800	375,000	95	1		96			242,000	94,600	37,800	375,000
Inorganics			305,000	305,000			85,800	85,800					219,000	219,000
Other	2,450	63,500		65,900	500	500		1,000			1,950	63,000		64,900
Total	438,000	462,000	360,000	1,260,000	21,500	79,000	85,800	186,000			416,000	383,000	275,000	1,070,000

Table 2.10 Waste quantities generated, diverted, combusted and landfilled by material in Saskatchewan

Waste Materials	Generated (tonnes)	Recycled (tonnes)	Backyard Composting (tonnes)	Central Composting (tonnes)	Sent For Combustion EFW Feed (tonnes)	Sent For Combustion non-EFW Feed (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)
	Total	Total	Res.	Total	Total	Total	Total	Total
Paper	293,000	30,000						263,000
Glass	45,900	7,800						38,100
Metals	135,000	60,000						75,200
Plastic	39,400	1,600						37,800
Organics	375,000		0	96				375,000
Inorganics	305,000	85,800						219,000
Other	65,900	1,000						64,900
Total	1,260,000	186,000	0	96				1,070,000

Population = 994,000
Per-capita generation (tonnes/cap.) = 1.27
Per-capita diversion (tonnes/cap.) = 0.19
Per-capita incineration (incl. ash/res.) (tonnes/cap.) = 0.00
Per-capita landfilled (incl. ash/res.) (tonnes/cap.) = 1.08

Notes:

1. For individual material categories, the quantities landfilled, combusted, composted and recycled may not equal the quantities generated. This is because the ash/residue generated during combustion appears in the Inorganic category, and it appears both in Ash/Residue as well as Landfilled columns.
2. All figures have been rounded to three significant digits.
3. The approach used to develop these estimates was adopted to meet the broad perspective of this project. Refer to section 2.1, paragraph 2 for additional information on the approach used.

Table 2.11 Waste quantities Northwest Territories, 1992

Waste Materials	Generated (tonnes)				Diverted (tonnes)				Sent for Combustion (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)			
	Residential	IC&I	C&D	Total	Residential	IC&I	C&D	Total	Total	Total	Residential	IC&I	C&D	Total
Paper	2,190	2,650	1,650	6,490	20	106		126			2,170	2,550	1,650	6,360
Glass	190	190		381	20	20		40			170	170		341
Metals	842	2,880	1,650	5,370	10	2,090		2,100			832	798	1,650	3,280
Plastic	425	844		1,270							425	844		1,270
Organics	1,370	3,490	7,210	12,100			991	991			1,370	3,490	6,220	11,100
Inorganics			20,700	20,700			10,600	10,600					10,100	10,100
Other	911	1,960		2,870							911	1,960		2,870
Total	5,920	12,000	31,200	49,100	50	2,210	11,600	13,800			5,870	9,810	19,600	35,300

Table 2.12 Waste quantities generated, diverted, combusted and landfilled by material in Northwest Territories

Waste Materials	Generated (tonnes)	Recycled (tonnes)	Backyard Composting (tonnes)	Central Composting (tonnes)	Sent For Combustion EFW Feed (tonnes)	Sent For Combustion non-EFW Feed (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)
	Total	Total	Res.	Total	Total	Total	Total	Total
Paper	6,490	126						6,360
Glass	381	40						341
Metals	5,370	2,100						3,280
Plastic	1,270							1,270
Organics	12,100	991						11,100
Inorganics	20,700	10,600						10,100
Other	2,870							2,870
Total	49,100	13,800	0	0				35,300

Population = 56,100
Per-capita generation (tonnes/cap.) = 0.88
Per-capita diversion (tonnes/cap.) = 0.25
Per-capita incineration (incl. ash/res.) (tonnes/cap.) = 0.00
Per-capita landfilled (incl. ash/res.) (tonnes/cap.) = 0.63

Notes:
1. For individual material categories, the quantities landfilled, combusted, composted and recycled may not equal the quantities generated. This is because the ash/residue generated during combustion appears in the Inorganic category, and it appears both in Ash/Residue as well as Landfilled columns.
2. All figures have been rounded to three significant digits.
3. The approach used to develop these estimates was adopted to meet the broad perspective of this project. Refer to section 2.1, paragraph 2 for additional information on the approach used.

Table 2.13 Waste quantities Manitoba, 1992

Waste Materials	Generated (tonnes)				Diverted (tonnes)				Sent for Combustion (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)			
	Residential	IC&I	C&D	Total	Residential	IC&I	C&D	Total	Total	Total	Residential	IC&I	C&D	Total
Paper	137,000	172,000	8,210	317,000							137,000	172,000	8,210	317,000
Glass	14,900	29,200		44,100	2,060			2,060			12,900	29,200		42,000
Metals	40,200	91,400	8,210	140,000	828	63,600		64,400			39,400	27,900	8,210	75,400
Plastic	11,900	32,200		44,100	627			627			11,300	32,200		43,500
Organics	252,000	100,000	35,900	389,000	1,410			1,410			251,000	100,000	35,900	387,000
Inorganicss			290,000	290,000			81,400	81,400					208,000	208,000
Other	8,510	67,400		75,900							8,510	67,400		75,900
Total	465,000	492,000	342,000	1,300,000	4,920	63,600	81,400	150,000			460,000	429,000	261,000	1,150,000

Table 2.14 Waste quantities generated, diverted, combusted and landfilled by material in Manitoba

Waste Materials	Generated (tonnes)	Recycled (tonnes)	Backyard Composting (tonnes)	Central Composting (tonnes)	Sent For Combustion EFW Feed (tonnes)	Sent For Combustion non-EFW Feed (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)
	Total	Total	Res.	Total	Total	Total	Total	Total
Paper	317,000							317,000
Glass	44,100	2,060		0				42,000
Metals	140,000	64,400		0				75,400
Plastic	44,100	627						43,500
Organics	389,000		537	874				387,000
Inorganics	290,000	81,400						208,000
Other	75,900							75,900
Total	1,300,000	148,000	537	874				1,150,000

Population = 1,090,000
Per-capita generation (tonnes/cap.) = 1.19
Per-capita diversion (tonnes/cap.) = 0.14
Per-capita incineration (incl. ash/res.) (tonnes/cap.) = 0.00
Per-capita landfilled (incl. ash/res.) (tonnes/cap.) = 1.05

Notes:
1. For individual material categories, the quantities landfilled, combusted, composted and recycled may not equal the quantities generated. This is because the ash/residue generated during combustion appears in the Inorganic category, and it appears both in Ash/Residue as well as Landfilled columns.
2. All figures have been rounded to three significant digits.
3. The approach used to develop these estimates was adopted to meet the broad perspective of this project. Refer to section 2.1, paragraph 2 for additional information on the approach used.

Table 2.15 Waste quantities Ontario, 1992

Waste Materials	Generated (tonnes)				Diverted (tonnes)				Sent for Combustion (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)			
	Residential	IC&I	C&D	Total	Residential	IC&I	C&D	Total	Total	Total	Residential	IC&I	C&D	Total
Paper	1,500,000	1,550,000	135,000	3,190,000	262,000	660,000	51,500	974,000	96,200		1,160,000	870,000	83,800	2,120,000
Glass	214,000	129,000		343,000	94,300	23,200		118,000	9,800		112,000	103,000		215,000
Metals	292,000	1,030,000	135,000	1,460,000	117,000	653,000	81,200	851,000	16,700		168,000	369,000	54,200	592,000
Plastic	244,000	365,000		610,000	5,990	15,500		21,500	23,200		224,000	341,000		565,000
Organics	1,710,000	662,000	592,000	2,960,000	226,000	96,600	355,000	678,000	102,000		1,400,000	551,000	237,000	2,180,000
Inorganics	64,800		4,290,000	4,360,000			3,680,000	3,680,000	3,800	83,100	124,000	20,300	612,000	756,000
Other	307,000	287,000		594,000		14,400		14,400	25,200		289,000	266,000		555,000
Total	4,330,000	4,030,000	5,160,000	13,500,000	705,000	1,460,000	4,170,000	6,340,000	277,000	83,100	3,480,000	2,520,000	986,000	6,990,000

Table 2.16 Waste quantities generated, diverted, combusted and landfilled by material in Ontario

Waste Materials	Generated (tonnes)	Recycled (tonnes)	Backyard Composting (tonnes)	Central Composting (tonnes)	Sent For Combustion EFW Feed (tonnes)	Sent For Combustion non-EFW Feed (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)
	Total	Total	Res.	Total	Total	Total	Total	Total
Paper	3,190,000	974,000			96,200			2,120,000
Glass	343,000	118,000			9,800			215,000
Metals	1,460,000	851,000			16,700			592,000
Plastic	610,000	21,500			23,200			565,000
Organics	2,960,000	355,000	90,400	232,000	102,000			2,180,000
Inorganics	4,360,000	3,680,000			3,800		83,100	756,000
Other	594,000	14,400			25,200			555,000
Total	13,500,000	6,020,000	90,400	232,000	277,000		83,100	6,990,000

Population = 9,620,000
Per-capita generation (tonnes/cap.) = 1.40
Per-capita diversion (tonnes/cap.) = 0.66
Per-capita incineration (incl. ash/res.) (tonnes/cap.) = 0.03
Per-capita landfilled (incl. ash/res.) (tonnes/cap.) = 0.73

Notes:
1. For individual material categories, the quantities landfilled, combusted, composted and recycled may not equal the quantities generated. This is because the ash/residue generated during combustion appears in the Inorganic category, and it appears both in Ash/Residue as well as Landfilled columns.
2. All figures have been rounded to three significant digits.
3. The approach used to develop these estimates was adopted to meet the broad perspective of this project. Refer to section 2.1, paragraph 2 for additional information on the approach used.

Table 2.17 Waste quantities Quebec, 1992

Waste Materials	Generated (tonnes)				Diverted (tonnes)				Sent for Combustion (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)			
	Residential	IC&I	C&D	Total	Residential	IC&I	C&D	Total	Total	Total	Residential	IC&I	C&D	Total
Paper	794,000	1,340,000	20,000	2,150,000	103,000	342,000		445,000	171,000		563,000	951,000	20,000	1,530,000
Glass	156,000	111,000		267,000	34,600	19,400		54,000	26,500		99,400	87,500		187,000
Metals	177,000	1,260,000	30,800	1,460,000	86,200	926,000		1,010,000	31,200		74,300	316,000	30,800	421,000
Plastic	166,000	314,000		480,000	2,770	30,200		33,000	42,500		133,000	272,000		404,000
Organics	919,000	570,000	216,000	1,700,000	22,000			22,000	191,000		731,000	545,000	216,000	1,490,000
Inorganics			1,320,000	1,320,000			173,000	173,000		162,000	130,000	32,500	1,140,000	1,300,000
Other	380,000	247,000	17,500	644,000	1,630	32,400		34,000	79,300		308,000	205,000	17,500	531,000
Total	2,590,000	3,840,000	1,600,000	8,030,000	250,000	1,350,000	173,000	1,770,000	541,000	162,000	2,040,000	2,410,000	1,430,000	5,880,000

Table 2.18 Waste quantities generated, diverted, combusted and landfilled by material in Quebec

Waste Materials	Generated (tonnes)	Recycled (tonnes)	Backyard Composting (tonnes)	Central Composting (tonnes)	Sent For Combustion EFW Feed (tonnes)	non-EFW Feed (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)
	Total	Total	Res.	Total	Total	Total	Total	Total
Paper	2,150,000	445,000			164,000	7,610		1,530,000
Glass	267,000	54,000			25,400	1,180		187,000
Metals	1,460,000	1,010,000			29,900	1,390		421,000
Plastic	480,000	33,000			40,600	1,890		404,000
Organics	1,700,000		1,480	20,500	182,000	8,480		1,490,000
Inorganics	1,320,000	173,000					162,000	1,300,000
Other	644,000	34,000			75,800	3,530		531,000
Total	8,030,000	1,750,000	1,480	20,500	517,000	24,100	162,000	5,880,000

Population = 6,920,000
Per-capita generation (tonnes/cap.) = 1.16
Per-capita diversion (tonnes/cap.) = 0.26
Per-capita incineration (incl. ash/res.)(tonnes/cap.) = 0.08
Per-capita landfilled (incl. ash/res.) (tonnes/cap.) = 0.85

Notes:

1. For individual material categories, the quantities landfilled, combusted, composted and recycled may not equal the quantities generated. This is because the ash/residue generated during combustion appears in the Inorganic category, and it appears both inAash/Residue as well as Landfilled columns.
2. All figures have been rounded to three significant digits.
3. The approach used to develop these estimates was adopted to meet the broad perspective of this project. Refer to section 2.1 paragraph 2 for additional information on the approach used.
4. Some of the above data does not correspond with those published in the official report of the Quebec Department of Environment and Wildlife. This is due primarily to the inclusion of certain categories of waste, such as automobile hulks, and to the use of different methods for calculating the volume of dry waste.

Table 2.19 Waste quantities New Brunswick, 1992

Waste Materials	Generated (tonnes)				Diverted (tonnes)				Sent for Combustion (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)			
	Residential	IC&I	C&D	Total	Residential	IC&I	C&D	Total	Total	Total	Residential	IC&I	C&D	Total
Paper	85,400	86,400	2,480	174,000	1,380	1,470		2,850			84,000	84,900	2,480	171,000
Glass	19,000	9,380		28,400	900	900		1,800			18,100	8,480		26,600
Metals	21,400	30,200	3,820	55,400	255	27,200		27,400			21,100	3,000	3,820	27,900
Plastic	16,600	18,800		35,400	1,350	1,350		2,690			15,300	17,400		32,700
Organics	59,300	72,700	26,700	159,000	644			644			58,700	72,700	26,700	158,000
Inorganics			107,000	107,000			6,930	6,930					100,000	100,000
Other	35,600	3,720		39,300							35,600	3,720		39,300
Total	237,000	221,000	140,000	598,000	4,520	30,900	6,930	42,400			233,000	190,000	133,000	556,000

Table 2.20 Waste quantities generated, diverted, combusted and landfilled by material in New Brunswick

Waste Materials	Generated (tonnes)	Recycled (tonnes)	Backyard Composting (tonnes)	Central Composting (tonnes)	Sent For Combustion EFW Feed (tonnes)	Sent For Combustion non-EFW Feed (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)
	Total	Total	Res.	Total	Total	Total	Total	Total
Paper	174,000	2,850						171,000
Glass	28,400	1,800						26,600
Metals	55,400	27,400						27,900
Plastic	35,400	2,690						32,700
Organics	159,000		14	630				158,000
Inorganics	107,000	6,930						100,000
Other	39,300							39,300
Total	598,000	41,700	14	630				556,000

Population = 728,000
Per-capita generation (tonnes/cap.) = 0.82
Per-capita diversion (tonnes/cap.) = 0.06
Per-capita incineration (incl. ash/res.) (tonnes/cap.) = 0.00
Per-capita landfilled (incl. ash/res.) (tonnes/cap.) = 0.76

Notes:
1. For individual material categories, the quantities landfilled, combusted, composted and recycled may not equal the quantities generated. This is because the ash/residue generated during combustion appears in the Inorganic category, and it appears both in Ash/Residue as well as Landfilled columns.
2. All figures have been rounded to three significant digits.
3. The approach used to develop these estimates was adopted to meet the broad perspective of this project. Refer to section 2.1 paragraph 2 for additional information on the approach used.

Table 2.21 Waste quantities Prince Edward Island, 1992

Waste Materials	Generated (tonnes)				Diverted (tonnes)				Sent for Combustion (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)			
	Residential	IC&I	C&D	Total	Residential	IC&I	C&D	Total	Total	Total	Residential	IC&I	C&D	Total
Paper	10,600	32,700	390	43,800	650	5,000		5,650	10,100		2,770	24,800	390	28,000
Glass	2,590	2,240	140	4,980	25	500		525	2,040		710	1,560	140	2,410
Metals	2,690	7,780	380	10,800	1,220	5,250		6,470	1,330		408	2,260	380	3,050
Plastic	2,830	7,180	125	10,100					2,800		781	6,430	125	7,340
Organics	11,800	13,300	1,770	26,800	336			336	9,670		3,160	11,900	1,770	16,800
Inorganics	589	2,190	2,990	5,770			238	238	655	8,950	7,320	3,750	2,750	13,800
Other	4,090	3,060	160	7,310		739		739	3,200		1,130	2,080	160	3,370
Total	35,200	68,500	5,950	110,000	2,230	11,500	238	14,000	29,800	8,950	16,300	52,800	5,710	74,800

Table 2.22 Waste quantities generated, diverted, combusted and landfilled by material in Prince Edward Island

Waste Materials	Generated (tonnes)	Recycled (tonnes)	Backyard Composting (tonnes)	Central Composting (tonnes)	Sent For Combustion EFW Feed (tonnes)	Sent For Combustion non-EFW Feed (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)
	Total	Total	Res.	Total	Total	Total	Total	Total
Paper	43,800	5,650			10,100			28,000
Glass	4,980	525			2,040			2,410
Metals	10,800	6,470			1,330			3,050
Plastic	10,100				2,800			7,340
Organics	26,800			336	9,670			16,800
Inorganics	5,770	238			655		8,950	13,800
Other	7,310	739			3,200			3,370
Total	110,000	13,600	0	336	29,800		8,950	74,800

Population = 130,000
Per-capita generation (tonnes/cap.) = 0.84
Per-capita diversion (tonnes/cap.) = 0.11
Per-capita incineration (incl. ash/res.) (tonnes/cap.) = 0.23
Per-capita landfilled (incl. ash/res.) (tonnes/cap.) = 0.57

Notes:
1. For individual material categories, the quantities landfilled, combusted, composted and recycled may not equal the quantities generated. This is because the ash/residue generated during combustion appears in the Inorganic category, and it appears both in Ash/Residue as well as Landfilled columns.
2. All figures have been rounded to three significant digits.
3. The approach used to develop these estimates was adopted to meet the broad perspective of this project. Refer to section 2.1 paragraph 2 for additional information on the approach used.

Table 2.23 Waste quantities Nova Scotia, 1992

Waste Materials	Generated (tonnes)				Diverted (tonnes)				Sent for Combustion (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)			
	Residential	IC&I	C&D	Total	Residential	IC&I	C&D	Total	Total	Total	Residential	IC&I	C&D	Total
Paper	108,000	147,000	1,760	257,000	6,960	13,400		20,300	19,900		86,900	128,000	1,760	216,000
Glass	25,200	10,100	632	35,900	1,540	1,540		3,090	3,680		20,400	8,180	632	29,200
Metals	25,300	46,600	1,720	73,700	359	33,800		34,100	3,050		22,400	12,300	1,720	36,500
Plastic	27,500	32,200	564	60,200	210	161		371	5,250		23,400	30,600	564	54,600
Organics	114,000	59,500	7,990	182,000	7,030			7,030	17,700		92,100	57,000	7,990	157,000
Inorganics	5,710	9,810	47,200	62,700			9,500	9,500	1,070	17,000	18,500	12,900	37,700	69,100
Other	39,700	10,400	722	50,800					6,020		34,100	9,940	722	44,800
Total	346,000	316,000	60,600	722,000	16,100	48,800	9,500	74,400	56,700	17,000	298,000	259,000	51,000	608,000

Table 2.24 Waste quantities generated, diverted, combusted and landfilled by material in Nova Scotia

Waste Materials	Generated (tonnes)	Recycled (tonnes)	Backyard Composting (tonnes)	Central Composting (tonnes)	Sent For Combustion EFW Feed (tonnes)	Sent For Combustion non-EFW Feed (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)
	Total	Total	Res.	Total	Total	Total	Total	Total
Paper	257,000	20,300			9,740	10,200		216,000
Glass	35,900	3,090			1,800	1,880		29,200
Metals	73,700	34,100			1,490	1,560		36,500
Plastic	60,200	371			2,570	2,680		54,600
Organics	182,000			7,030	8,660	9,050		157,000
Inorganics	62,700	9,500			525	548	17,000	69,100
Other	50,800				2,940	3,080		44,800
Total	722,000	67,400	0	7,030	27,700	29,000	17,000	608,000

Population = 903,000
Per-capita generation (tonnes/cap.) = 0.80
Per-capita diversion (tonnes/cap.) = 0.08
Per-capita incineration (incl. ash/res.) (tonnes/cap.) = 0.06
Per-capita landfilled (incl. ash/res.) (tonnes/cap.) = 0.67

Notes:
1. For individual material categories, the quantities landfilled, combusted, composted and recycled may not equal the quantities generated. This is because the ash/residue generated during combustion appears in the Inorganic category, and it appears both in Ash/Residue as well as Landfilled columns.
2. All figures have been rounded to three significant digits.
3. The approach used to develop these estimates was adopted to meet the broad perspective of this project. Refer to section 2.1 paragraph 2 for additional information on the approach used.

Table 2.25. Waste quantities Newfoundland, 1992

Waste Materials	Generated (tonnes)				Diverted (tonnes)				Sent for Combustion (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)			
	Residential	IC&I	C&D	Total	Residential	IC&I	C&D	Total	Total	Total	Residential	IC&I	C&D	Total
Paper	60,100	124,000	1,170	186,000	431	431		861	13,600		49,300	121,000	1,170	171,000
Glass	13,400	13,500	420	27,300	18	18		36	2,670		11,000	13,100	420	24,600
Metals	15,000	26,000	1,140	42,200	47	21,300		21,400	2,730		12,400	4,530	1,140	18,000
Plastic	11,700	27,000	375	39,100	422	422		843	2,650		9,310	25,900	375	35,600
Organics	41,700	105,000	5,310	152,000	800	94		894	9,820		33,800	102,000	5,310	141,000
Inorganics			20,600	20,600			3,960	3,960		10,600	8,520	2,130	16,700	27,300
Other	25,000	5,360	480	30,900	1,960	3,440		5,400	4,070		19,100	1,870	480	21,400
Total	167,000	301,000	29,500	498,000	3,670	25,700	3,960	33,400	35,500	10,600	143,000	270,000	25,600	439,000

Table 2.26 Waste quantities generated, diverted, combusted and landfilled by material in Newfoundland

Waste Materials	Generated (tonnes)	Recycled (tonnes)	Backyard Composting (tonnes)	Central Composting (tonnes)	Sent For Combustion EFW Feed (tonnes)	Sent For Combustion non-EFW Feed (tonnes)	Ash/Residue Landfilled (tonnes)	Landfilled (tonnes)
	Total	Total	Res.	Total	Total	Total	Total	Total
Paper	186,000	861				13,600		171,000
Glass	27,300	36				2,670		24,600
Metals	42,200	21,400				2,730		18,000
Plastic	39,100	843				2,650		35,600
Organics	152,000			894		9,820		141,000
Inorganics	20,600	3,960					10,600	27,300
Other	30,900	5,400				4,070		21,400
Total	498,000	32,500	0	894	0	35,500	10,600	439,000

Population = 576,000
Per-capita generation (tonnes/cap.) = 0.86
Per-capita diversion (tonnes/cap.) = 0.06
Per-capita incineration (incl. ash/res.) (tonnes/cap.) = 0.06
Per-capita landfilled (incl. ash/res.) (tonnes/cap.) = 0.76

Notes:
1. For individual material categories, the quantities landfilled, combusted, composted and recycled may not equal the quantities generated. This is because the ash/residue generated during combustion appears in the Inorganic category, and it appears both in Ash/Residue as well as Landfilled columns.
2. All figures have been rounded to three significant digits.
3. The approach used to develop these estimates was adopted to meet the broad perspective of this project. Refer to section 2.1, paragraph 2 for additional information on the approach used.

Section 3

Cost and Employment Estimates

3.1 Introduction

Estimates of the economic dimensions of solid waste management in Canada are provided in this section. This includes the annual operating and maintenance costs of the current waste management system, an estimate of the value of the current waste management system, referred to as its replacement cost, and an estimate of current employment levels in solid waste management activities. The information presented in section 2, along with data from a number of sources, was used to develop these estimates. They have been developed using 1992 as the base year.

The results of the analysis are in section 3.2. How estimates were developed, the assumptions used, and the limitations of the approach are in sections 3.3 to 3.7. Detailed costing tables used for the analysis are in appendix B.

3.2 Summary of Cost and Employment Estimates

The approximate costs of solid waste management in Canada in 1992 were developed using available data sources. These preliminary estimates indicate:

- $2.2 billion is expended annually on operating and maintenance costs of waste management in Canada, including waste and recyclables collection and processing (including recycling and composting), incineration (with and without energy recovery) and disposal.
- Of the total expended each year, 37% is for managing residential waste, and 63% is for managing IC&I and C&D waste.
- If the annualized capital costs are included, the cost of the Canadian solid waste management system is approximately $2.76 to $3.33 billion.
- Of the total expended on waste management, approximately $1.2 billion or 41% is expended on diversion activities, and approximately $1.8 billion, or 59% of the total, is expended on disposal.
- The current waste management infrastructure has a replacement value of approximately $5.16 billion. Of this total;
  - 35% is for landfills;
  - 29% is for recycling plants;
  - 13% is for recycling trucks;
  - 12% is for garbage trucks;
  - 6% is for EFW plants;
  - 2% is for composting facilities;
  - 1% is for landfill gas recovery projects;
  - 1% is for backyard composters;
  - <1% is for incineration facilities without energy recovery; and
  - <1% is for organic waste collection trucks.

The extent to which privately owned installation such as material recovery facilities (MRFs), landfills, incinerators, energy-from-waste (EFWs) and composting facilities are included in the cost estimates depends on availability of published information and the methods used to calculate costs. All waste generation estimates are based on information collected and synthesized in section 2.

Furthermore, waste management cost estimates were based on limited private sector cost information and, where necessary, municipal cost information was used to The provincial/ territorial data for the total waste stream by material is in the second table. supplement inadequate private sector cost information.

Direct employment related to solid waste management in Canada (including residential, IC&I and C&D waste management services) in 1992 is estimated at 21,000 employees. Of this total, approximately 3,480 (16%) of the jobs are in the public sector, and approximately 17,500 (84%) are in the private sector. Approximately 7% of jobs are in public and private sector ventures (Statistics Canada, 1993).

Sections 3.3 to 3.7.2 discuss how each of the estimates was developed and the limitations of the estimation methods. The working tables used to develop the estimates are in appendix B.

3.3 Method Used to Develop Cost Estimates

The waste quantity estimates developed in section 2 are the basis for the cost estimates presented in this section. The number of tonnes of waste managed by each method in 1992 (recycling, composting, incineration and landfill) was identified in section 2. Typical unit costs (in $/tonne) for each management method and for waste collection were identified through a review of the literature and from in-house data. These rates were applied to the quantities of waste managed by each method to estimate the operating and maintenance costs of the Canadian waste management system in 1992.

The value of the current Canadian waste management infrastructure was estimated by first identifying the number of each type of facility in place. This estimate is restricted by a lack of information on waste management facilities owned by the private sector, and is limited to facilities identified through published reports, Environment Canada information, and information available through in-house RIS files. Existing facilities were assigned to different size ranges (to account for changing cost structures associated with different sized facilities), and typical capital costs (sometimes expressed as $/tonne of daily or annual processing capacity) were used to develop first order estimates.

Annualized capital costs were developed for each type of facility by either using an annualized capital allowance found in the literature, or by estimating the capital costs of facilities, and estimating the annualized capital allowance using the following amortization periods:

Buildings with equipment	20 years
Trucks/composting facilities	7 years

Interest rates used in the analysis depended on the source of the information. Where annualized capital costs were developed by the study team, (rather than a published source of annualized cost allowances), an interest rate of 7% was used. A series of tables on how the costs were developed is in appendix B.

3.3.1 Landfills

Annual Operating Costs

The waste quantity estimates (section 2) indicate that approximately 22.5 million tonnes of waste is landfilled in Canada each year. This study attempts to assess the annual costs of landfilling in Canada taking operating conditions at various sizes of landfill into account. The task was somewhat limited by the fact that an up-to-date inventory of all landfills in Canada that accept municipal solid waste was not available. However, Environment Canada data includes the largest landfills in each province and was considered a reasonable basis for this level of estimate. No information was available on the size and number of small, rural landfills scattered throughout the provinces, but effort was made to account for these smallest landfills in the cost calculations.

A survey carried out by Environment Canada (for a recent landfill gas recovery project) identified the largest landfills in each province. A total of 113 landfills was identified, and the total disposal capacity of each landfill was provided along with the remaining capacity. This information was used to generate estimates of the amount of waste landfilled annually at each site.

Each landfill was placed in one of four categories, based on its total design capacity. These size ranges were: 0-500,000 tonnes; 500,001- 4,000,000 tonnes; 4,000,001-7,000,000 tonnes; and over 7,000,000 tonnes. These ranges helped estimate costs projected for different sizes of landfill (VHB and Maclaren, 1991; GVRD, 1993D).

The annual capital and operating costs for different sized landfills, acquired from various studies (VHB and MacLaren, 1991; GVRD, 1993D), were used to estimate the overall operating and capital costs for each range of landfill (on a cost per tonne basis). In general, as the size of the landfill increases, the capital and operating costs per tonne decrease. When expressed on a $/tonne basis, for example, the operating costs for the smallest landfills ranged from $6.91/tonne to $41.30/tonne. The operating costs for landfills with a total capacity of greater than 7,000,000 tonnes ranged from $0.94/tonne to $12.50/tonne. The average operating costs for the various sized landfills was $14.53/tonne. The operating costs were applied to the amount of waste received annually for each of the identified landfills. The costs estimated by this method were then extrapolated to cover the total of 22.5 million tonnes landfilled in 1992. Tables used to develop the landfill cost estimates are included in appendix B.

In order to estimate the operating costs for landfills, the overall capacity had to be adjusted to reflect the annual disposal rate. Information was obtained on the expected life of each reported landfill (i.e., 20 years, 25 years or 50 years). From this an estimated annual disposal rate was calculated and the operating costs applied. Operating costs were also estimated for additional waste not captured in the reports (i.e., unreported small landfills and private landfills for C&D waste).

Capital Costs

An estimate of the capital costs of landfills currently in place in Canada was developed using typical costs for different size ranges of landfills reported in a number of cost studies (VHB & MacLaren, 1991; GVRD, 1993D). The 113 largest landfills were assigned to various size ranges. Capital costs for these facilities were provided on a per-tonne-of-design-capacity basis in the various cost studies used for the analysis. These reported typical costs ranging from $19.10 to $22.42/tonne for very small landfills (with a total design capacity of 0-500,000 tonnes) to $1.89 to $7.89/tonne for large landfills (with a total design capacity of greater than 7,000,000 tonnes). The average capital cost for the various sized landfills was $7.75/tonne of capacity (before amortization).

Perpetual Care Costs

Perpetual care costs were also included in the total costs, since communities must factor them into the overall costs to operate and maintain a landfill. These perpetual care costs assume a large share of the total costs, equaling almost three quarters the capital costs, or approximately $5.81/tonne (before amortization) for the various sized landfills. The calculations of the costs of the landfills in the different categories (based on existing cost information for similar sized landfills) are in appendix B.

3.3.2 Landfill Gas Recovery Projects

A recent Environment Canada project identified 24 landfill gas recovery projects in Canada. The survey identified the number of landfills throughout Canada with gas recovery systems and the size of the systems. This information was confirmed by Hickling and Emcon (1994) in their report about options for managing emissions from solid waste landfills. The same report also provided an equation for estimating the capital cost associated with different sized systems. This equation was applied to the information gathered in the Environment Canada survey to estimate the replacement capital costs of the 24 existing landfill gas recovery installations in Canada. Using the formulas provided in the Hickling and Emcon report, the estimated capital costs for the landfill gas recovery systems in Canada in 1992 is approximately $68,000,000.

The operating costs for a landfill gas recovery project tend to be limited to the salaries for operators and overhead costs (Hickling and Emcon, 1994), which are assumed to be included in the annual operating costs of the landfill where the installation is located.

3.3.3 Energy From Wastes and Incinerators

A 1994 survey by Environment Canada provided information about many of Canada's EFW facilities and incinerators existing in 1992. In-house information available from the RIS resource centre determined which facilities functioned as EFWs and which functioned solely as incinerators. Information about the small incinerators in operation throughout Nova Scotia augmented the Environment Canada survey (see references).

Capital and Operating Costs

Annual capital and operating costs were calculated separately for EFWs and incinerators without energy recovery. The capital and operating costs for the incinerators were derived from several waste management master plans recently completed for Nova Scotia (Vaughan et al., 1994; Neill and Gunter et al., 1994). These studies not only provided the existing costs for small incinerators located throughout the province, but also estimated the costs for new incinerators. Capital costs (before amortization) for incinerators ranged from $218/tonne to $235/tonne of design capacity. Operating costs reported for incinerators averaged $30/tonne. Operating costs, including annualized capital costs, for incinerators ranged from $45/tonne to $57/tonne.

Various documents were used to calculate the capital and operating costs for EFW facilities, including annual reports on the Burnaby and Peel EFWs (GVRD, 1993A and Peel, 1990). Further information about the remaining Ontario based EFWs was extracted from a report written for the Ontario Ministry of the Environment (1992) which examined the costs for Victoria Hospital, London and Solid Waste Reduction Unit (SWARU), Hamilton. The data was then used to estimate the capital and operating costs for the remaining two EFWs. Capital costs for EFWs ranged from $398/tonne of capacity to $507/tonne of design capacity. Reported average operating costs for an EFW plant was $38/tonne. Operating costs, including annualized capital costs, for EFWs ranged from $72/tonne to $85/tonne.

3.3.4 Material Recovery Facilities

General

Information about the number of municipal MRFs operating in Canada was obtained from RIS in-house files and published reports (Graham, 1994 GVRD, 1993B). No information is available on the number of MRFs operated for the IC&I and C&D sectors.

The amount of recyclables diverted in 1992, which would typically be processed in MRFs, was estimated in section 2. This quantity formed the basis of the MRF and processing cost estimates.

In order to estimate the costs associated with processing C&D recyclables, the concrete and asphalt recyclables were removed from the total amount processed. Most concrete and asphalt is source separated on-site, which eliminates the need for further processing at a MRF. The operating costs associated with this activity are nominal (GVRD, 1993B).

Operating Costs

The operating costs for municipal MRFs were collected from one source (Graham, 1994). In this study, Ontario municipalities provided detailed information on the capital and operating costs associated with their MRFs. Different operating and capital costs were acquired for municipal MRFs of different sizes. Annual operating costs established on a per tonne basis were used to calculate the average annual operating costs for recyclables processed at the municipal MRFs. Operating costs for a municipal MRF including the amortized capital costs range from $83/tonne to $102/tonne. These operating costs are gross operating costs, before revenues.

Operating costs for private sector MRFs, processing IC&I and C&D recyclables, were taken from the greater Toronto area 3Rs analysis report prepared for the Ontario Ministry of Environment and Energy (1994). The operating costs are based on the per tonne costs charged to process IC&I and C&D recyclables by private sector recycling companies. It was assumed that the amortized capital costs and profit are built into the prices charged by private sector operators to their clients. These processing costs were used to calculate the annual operating costs for IC&I and C&D recyclables. The estimated annual operating costs (including the amortized capital costs) to process recyclables at designated IC&I material recovery facilities range from $115 to $135/tonne and the estimated operating costs (including the amortized capital costs) to process recyclables at designated C&D material recovery facilities range from $75 to $85/tonne.

Capital Costs

Capital costs of MRFs were collected from two main sources (MOEE, 1994 ;Graham, 1994). As part of a cost-effectiveness study being completed for Ontario Multi-material Recycling Inc. (OMRI), Ontario municipalities were asked to provide detailed information on the capital and operating costs associated with their MRFs. Different capital costs were acquired for different sized MRFs, with the capital costs ranking from $28/tonne to $34/tonne. In estimating the costs for the MRFs in Canada, an average throughput of each residential MRF was calculated and the most applicable capital cost from the Ontario situation was then applied on a per tonne throughput basis. The average per tonne capital costs were used to calculate the costs associated with the IC&I and C&D MRFs since it was assumed that the facility design would be similar.

3.3.5 Composting Facilities

A comprehensive listing of leaf and yard waste compost facilities (provided by the Composting Council of Canada, 1993) was used to determine the number of facilities in operation throughout Canada. The facilities were organized according to different sizes: 0-5,000 tonnes/year; 5001-25,000 tonnes/year; and greater than 25,000 tonnes/year. These sizes correspond with recognizable changes in the operating costs. The overall amount of material throughput varies from that estimated in the waste generation tables since some facilities process other materials (such as sewage sludge) not considered part of the municipal waste stream. Also, wood waste generated by the C&D sector is assumed not to be composted with leaf and yard waste. The C&D wood waste accounts for approximately 4,500 tonnes of organic material reported to have been diverted from disposal in Canada in 1992. The estimated throughput corresponds with diversion estimates generated in section 2.

Capital and Operating Costs

Capital and operating costs for the different sizes of compost facilities were estimated using information provided in a report prepared for the Greater Vancouver Regional District (GVRD, 1993C) and the Nova Scotia Government (Angus Environmental Limited, 1994). The amortized capital costs range from $29 to $47/tonne for windrow facilities with a capacity of 5,000 tonnes or less, and from $28 to $39/tonne for facilities with a capacity greater than 5,000 tonnes. The operating costs ranged from $16/tonne to $26/tonne.

3.3.6 Backyard Composters

A survey conducted for Environment Canada by Senes identified the number of backyard composters issued by larger urban centres across Canada in 1992 at approximately 726,000. Estimates of backyard composter use were not provided for Newfoundland, Prince Edward Island, Nova Scotia, Saskatchewan, Alberta, Northwest Territories and Yukon. Diversion through backyard composters was estimated using an average diversion rate of 135 kg/composter/year. This figure was derived using data from a Region of Peel study which indicated a diversion rate of 169 kg/composter/year in composters used effectively, and an effective participation rate of 80%.

Operating Costs

Costs associated with backyard composting programs were estimated in a number of reports (Compost Management Associates, 1992 Rivers, 1994; and Centre and South Hastings, 1994). Reported values range from $21/tonne, based on a ten year composter life (Region of Durham) to $45/tonne(Region of Peel). Costs used to develop the estimates ranged from $25 per tonne to $45 per tonne of waste processed through the backyard composter. These costs included capital costs of the backyard composter units.

Capital Costs

Capital costs of backyard composters were estimated assuming that each unit costs $50 to $60. Prices vary, depending on the number of units ordered at one time, and benefit from economies of scale (i.e., large orders cost less per unit). The capital cost is included in the costs described under operating costs.

3.3.7 Waste and Recyclables Collection Costs

Operating Costs

Collection costs were based on information provided in a 3Rs report prepared for the Ontario Ministry of Environment and Energy (1994). Collection costs (including amortized capital costs) for recyclables, leaf and yard, and waste collection were provided on a per tonne basis by several municipalities located in the greater Toronto area. The costs were averaged and applied to estimates generated for waste disposal, recycling, and composting throughout Canada as presented in section 2. Garbage collection costs are estimated at $47/tonne (for residential and IC&I waste), leaf and yard waste collection costs are estimated at $73/tonne, residential recyclables collection costs are estimated at $101/tonne, and IC&I and C&D recyclables collection costs are estimated at $50/tonne.

Capital Costs

The number of trucks involved in all collection activities was estimated using typical collection efficiency values (in tonnes/truck/day) applied to the number of tonnes transported by the Canadian waste management system in 1992 (presented in section 2). The efficiency factors were obtained from RIS in-house files. The above approach yielded an estimate of 6,563 recycling trucks and 6,928 organic waste/garbage trucks in operation in 1992. The capital costs of collection trucks for garbage, recyclables and organics were estimated assuming that all trucks cost $100,000 per unit.

3.3.8 Employment in Waste Management

Limited information is available on employment levels in the waste management industry. Some data were extracted from a number of sources (Statistics Canada, 1993; OWMA, 1994) to generate estimates on the number of municipal and private sector employees involved in waste management (including recycling and composting) in Canada in 1992.

A Statistics Canada survey of municipalities identified the ratio of public and private sector employees involved in municipal (predominantly residential service only) waste management throughout Canada. Municipalities in the Atlantic provinces use 50% public, 43% private, and 7% combined sector employees for residential waste management activities. Quebec municipalities use 44% public, 52% private and 4% combined sector employees. Ontario municipalities use 49% public, 38% private, and 13% combined sector employees. The prairies use 43% public, 33% private and 24% combined sector employees. British Columbia uses 40% public, 47% private and 13% combined sector employees. No information was provided for the Northwest Territories or Yukon. This information was used to identify the percentage of public and private sector involvement in municipal waste management activities throughout Canada.

It is assumed that private sector waste management companies serve all the IC&I and C&D sectors by collecting and processing their wastes and recyclables. No information was available to determine the amount of public versus private sector involvement in waste management activities targetting the IC&I and C&D sectors.

To estimate the number of public and private sector employees providing waste management services to municipal (residential), IC&I and C&D sectors, information that could be extrapolated to the rest of Canada was required on the number of employees in each sector . The Ontario Waste Management Association (OWMA) published information about the number of people employed by private sector waste management companies in Ontario in 1992. It was known that 4,330,000 tonnes of residential waste and 9,190,000 tonnes of IC&I and C&D waste were generated in Ontario in 1992. The portion of private sector employment in both sectors was also previously estimated. This information was applied to the waste generated in Ontario that is collected and processed by the private sector from which a tonnage per employee was calculated. An estimated 1,580 tonnes of waste is collected or processed per employee annually. Using this estimate, it was possible to calculate the number of people employed in the waste management industry across Canada.

3.4 Waste Management Facilities in Canada

Data on the estimated number of solid waste management facilities of various types in Canada are in table 3.1. This information was used to develop estimates of the value of the Canadian solid waste management infrastructure and was obtained from a number of sources including:

- published waste management reports from various cities and provinces (see list of references at the end of the section);
- published and unpublished reports on specific technologies (such as incineration and landfill gas recovery projects) provided by Environment Canada; and
- RIS in-house files.

3.5 Annual Waste Management Costs in Canada

Estimates of the annual costs of waste management in Canada are in table 3.2. The first column presents annual operating and maintenance costs, the second column presents estimates of annualized capital costs of various system components, and the third column presents annual costs which include annualized capital.

3.5.1 Analysis of Operating Cost Information

The annual operating and maintenance (O&M) costs of the Canadian solid waste management system are approximately $2.2 billion. These costs include collection, handling, processing, and disposal of residential, IC&I/C&D wastes

Table 3.1 Estimated number of solid waste management facilities in Canada

Facility Type	Estimated in Canada*	Sources of Information and Limitations of Data
Landfills	112	Environment Canada survey of operating landfills in each province, 1993
Landfill gas recovery projects	24	Environment Canada survey of landfills with gas recovery systems, 1993 Hickling and Emcon, 1994
EFW plants	10	Environment Canada survey of EFW plants in Canada, 1994
Incinerators (without energy recovery)	15	Environment Canada survey of incinerators in Canada, 1994
Recycling plants (MRFs) (municipal only)	145	GVRD Report , 1994 Ontario MRF Survey, RIS files
Central composting facilities (mostly consisting of leaf and yard waste facilities)	86	Composting Council of Canada Survey, 1993, and Environment Canada Survey of Solid Waste Composting Operations in Canada, 1993
Backyard composters	727,000	Environment Canada Survey of Solid Waste Composting Operations in Canada, 1993
Recycling trucks	6,560	RIS estimates
Organic waste collection trucks and garbage trucks	6,930	RIS estimates

* based on available information

and recyclables generated throughout Canada. Annualized capital costs are approximately $819 million, for a total annual cost of approximately $3 billion.

Most of the annual costs associated with waste management are operating and maintenance costs (73%), with less than one third of the costs used to pay for amortized capital(27%), if most of the capital costs associated with waste management facilties is amortized over a 20-year period (table 3.2).

Garbage collection alone (over $1 billion) accounts for the greatest portion of money expended on solid waste management each year in Canada, accounting for 34% of the annual waste management system costs (including amortized capital costs). Landfill operation accounts for an annual cost of $294 million for ongoing O&M costs (13% of the annual O&M expenditure), or $654 million/year, if amortized capital costs are included in the estimate. The capital costs of landfill may be somewhat overestimated in this analysis, as the replacement cost, rather than the original invested capital cost, has been estimated. However, as old landfills across Canada are replaced with new, more expensive facilities, this estimate will hold true as a reflection of annual expenditures in the future, when the costs of landfill will be higher.

Table 3.2 Annual operating costs of Canadian waste management system

Operation	Annual O&M Costs ($ million)	Annualized Capital Costs ($ million)	Total Annual Costs (Capital & O&M) ($ million)
Garbage collection	$969	$124	$1,093
Incineration	$2.3	$3.3	$5.6
EFW (net of revenue)	$60	$28	$88
Landfill (including gas recovery)	$292	$359	$651
Recyclables collection	$426	$110	$536
Recyclables processing (net of revenue)	$448	$176	$624
Organics collection	$19.1	$3.9	$23
Organics composting	$6.7	$11	$17.7
Backyard composting	$0.034	$3.4	$3.43
TOTAL	**$2,222**	**$819**	**$3,042**

The percentage breakdown of total annual capital and operating costs is presented in figure 3.1.

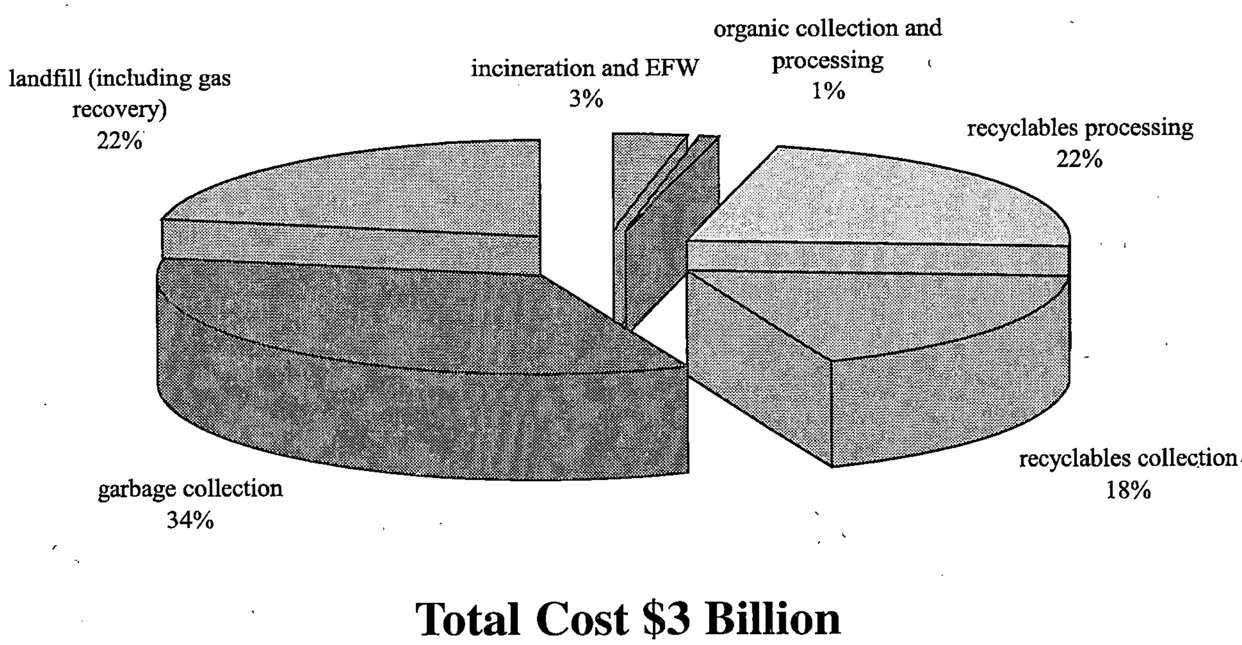

Figure 3.1 Percentage breakdown of total annual capital and operating costs

Recycling collection and processing activities account for an estimated $910 million per year, or 41% of system operating and maintenance costs. If annualized capital costs are included, recycling collection and processing account for $1.2 billion, or 40% of the annual system cost.

3.5.2 Limitations of Approach

The accuracy of the cost estimates is based on the availability of information about the types, numbers and capacities of waste management system components throughout Canada, including most of the waste management facilities that existed in 1992. However, a few smaller landfills and some other smaller facilities (i.e., composting and incineration) may not be represented in the data.

Furthermore, very little information has been obtained from the private sector regarding the number, capacities, and operating characteristics of privately owned and operated facilities, such as MRFs used to process IC&I and C&D recyclable materials. Costs for privately owned facilities were developed using a unit cost approach applied to the estimated number of tonnes managed by each method. Capital costs of privately owned facilities were not estimated, due to a lack of data on the number and size of these facilities. However, the costs developed for management of private sector wastes included an allowance for capital costs, which was assumed to be included in the prices charged to the private sector for waste management.

Costs of the waste management system were developed using a unit cost approach. This approach does not take into consideration economies of scale depending on the size of programs, and factors such as distance to market and so on, which affect the costs of some programs. In spite of some limitations, this

Table 3.3 Estimated value of current Canadian solid waste management infrastructure (1992)

Facility Type	Estimated Number*	Value ($ million)
Landfills	112	1,787
Incinerators	15	25
EFW plants	10	297
Landfill gas recovery projects	24	68
Composting sites	86	122
Backyard composters	727,158	49
MRFs	145	1,500
Recycling trucks	6,563	656
Leaf and yard waste collection trucks	210	21
Garbage trucks	6,718	637
TOTAL	**not applicable**	**5,162**

* based on available information

The percentage distribution of the total values associated with various waste management activities is in figure 3.2.

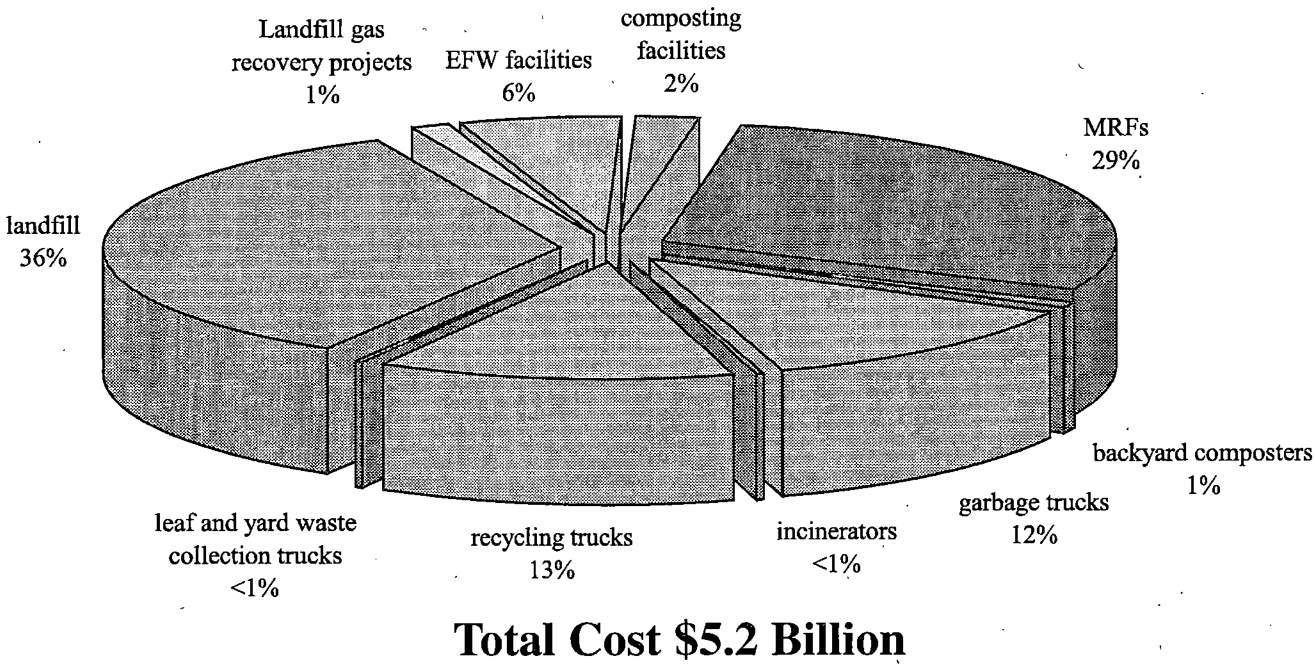

Figure 3.2 Percentage breakdown of Canadian solid waste management infrastructure value

approach is considered reasonable to develop a first order estimate of the annual costs of the Canadian waste management system.

3.6 *Value of Canadian Waste Management System Infrastructure*

Estimates of the value of the major components of the current waste management system in Canada identified during this study are in table 3.3. As discussed previously, information pertaining to private sector facilities is limited due to a lack of information on the number and type of facilities involved. Instead, information on the amount of waste generated and diverted by the IC&I and C&D was substituted. Numbers of trucks used to transport private sector waste for disposal and recycling purposes were also estimated using available waste generation and diversion data. The total value of the current infrastructure is approximately $4.2 to $6.1 billion. This estimate is based on the total capital cost of waste management facilities in existence in 1993. New facilities constructed after 1993 are not reflected in the sunk cost estimates.

3.6.1 *Analysis of Capital Cost Data*

The current value of the waste management infrastructure in Canada refers to the amount of capital cost sunk into existing waste management facilities and vehicles, recognizing that the capital costs are amortized over time. The sunk costs are developed from information from the early 1990s.

Landfills and garbage collection vehicles represent 48% of the sunk capital costs, followed by recycling facilities and collection trucks at 42% of the sunk capital costs. The remaining costs are related to incinerators/EFWs (7% of the sunk capital costs) and composting facilities (2% of the sunk capital costs).

Many of the landfills have a life span of 20 years or more and therefore, while the amount of capital expended on the construction of landfills seems proportionately high, it is costed over a minimum of 20 or more years. MRFs and EFWs/ incinerators also tend to be costed over their expected life span (20 years). The remaining facilities (composting windrow facilities and incinerators) are amortized over 10 years.

3.6.2 Limitations of Estimate

The accuracy of the cost estimates is based on the availability of information about the types, numbers, and capacities of waste management system components throughout Canada. While the available information identified the largest of the facilities, there is reason to believe that few of the smaller landfills, incinerators, and composting facilities are represented in the inventories.

3.7 Employment in Waste Management in Canada

The entire waste management industry in Canada (serving the residential, IC&I and C&D sectors) employs over 21,000 full time workers, of which 16% are with the municipal sector and 84% are with the private sector. A breakdown of numbers of employees in each of the waste management systems is in table 3.4. These estimates are calculated using the average number of tonnes processed annually per employee (1,580 tonnes/employee) divided into the waste generation and diversion estimates developed in section 2.

3.7.1 Analysis of the Information

The majority of the waste management operations (84%) is conducted by the private sector (since the private sector is generally responsible for all IC&I and C&D collection and processing activities). Municipal agencies across Canada on average use 50% municipal and 50% private sector employees to operate residential waste management collection and processing programs. Whereas the public and private sectors tend to share the responsibilities associated with waste collection and disposal, the private sector dominates the collection and processing of residential recycling programs.

3.7.2 Limitations of Approach

No published information was available on the size of the waste management industry in Canada. One source, the Ontario Waste Management Association, published the number of private sector employees involved in waste management in Ontario. This number was used to estimate the number of tonnes handled per employee and extrapolated to the rest of Ontario and Canada. It was assumed that the OWMA represents all or most private sector companies in Ontario and therefore has published a number that accurately reveals private sector employment in Ontario. This is believed to be a fairly sound assumption.

The application of a rate of tonnes handled per employee assumes that all jurisdictions and companies work with uniform efficiency. This assumption has some limitations, but is considered the most reasonable approach for the purposes of the study. The majority of waste management operations is assumed to be operated by the private sector, whose tonnage rate per employee is used to develop the national estimate.

It has also been assumed that the same amount of time is required to collect and process waste, recyclables and compostables. This is not really the case. For example, curbside collection of recyclables is more time consuming than curbside collection of waste, and more processing time and effort is required to process recyclables than compost or waste.

It was assumed that all IC&I and C&D waste management requirements are handled by the private sector. In-house files and experience support this assumption.

Table 3.4 Estimated employment in solid waste management activities in Canada

Facility Type	Estimated Number of Employees	Percentage of Total Employment
Landfills (including gas recovery systems) and associated garbage truck operators	14,070	67
EFW plants and associated garbage truck operators	420	2
Incinerators (no energy recovery) and associated garbage truck operators	110	<1
Recycling plants (MRFs) and recycling truck operators	6,090	29
Central composting facilities and leaf and yard waste truck operators	210	1
Backyard composter program management	99	<1
(including promotion/education and distribution)		
TOTAL	**21,000**	**100**

The percentage breakdown of employees involved in different solid waste management activities is presented in figure 3.3.

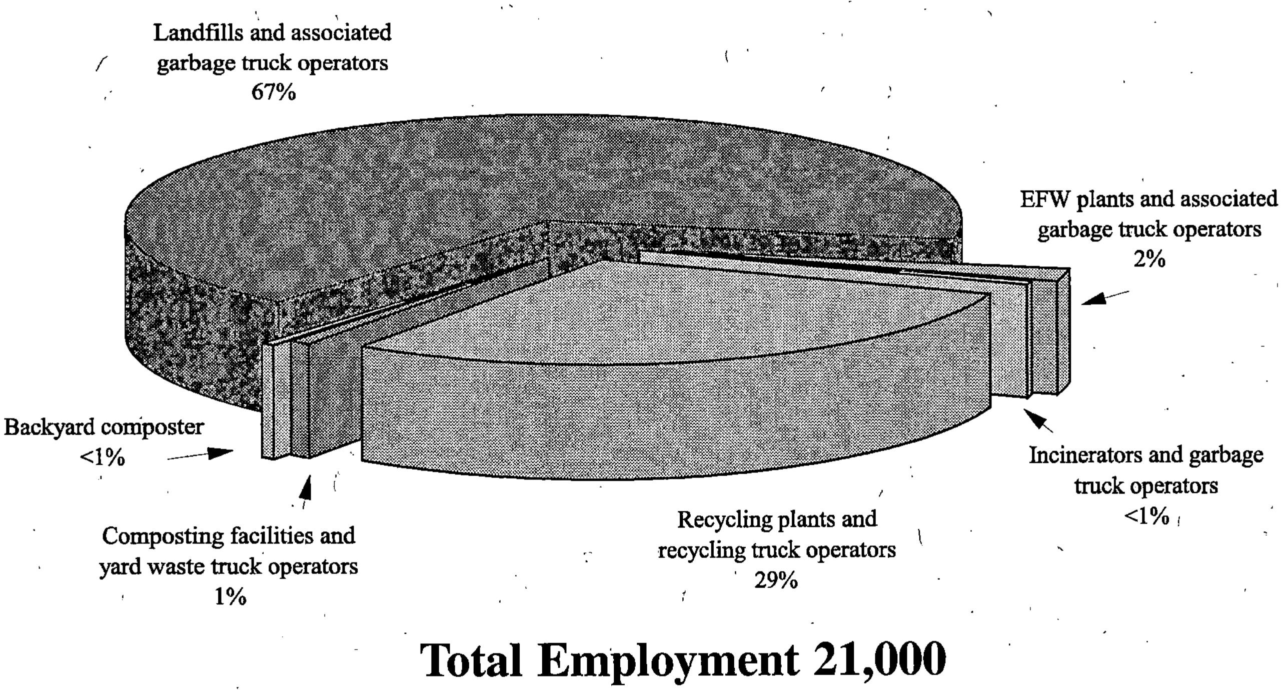

Figure 3.3 Percentage employment in solid waste management activities

3.8 References

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Section 4

Energy Estimates

4.1 Introduction

Estimates of the energy impacts of waste management in Canada are done in this section. It includes estimates of the energy expended for solid waste collection, processing, combustion and landfilling, an estimate of the energy content of waste landfilled and combusted without energy recovery, and an estimate of the energy currently recovered from waste. The potential energy saved through recycling of some waste streams is also addressed. The waste quantity information presented in section 2 was used to develop these estimates.

The results of the analysis are presented in this section, along with a brief description of how the estimates were developed. A detailed description of the estimates energy is in appendix C, and tables containing provincial energy estimates are in appendix D.

4.2 Assumptions Used to Estimate Energy Expended on Solid Waste Management

The energy expended in solid waste management was estimated by breaking the activity into separate elements, including:

- residential, IC&I and C&D waste collection;
- residential, IC&I and C&D recyclables collection;
- waste transfer, handling and shipment;
- waste landfilling;
- recyclables processing;
- combustion (EFW and non-EFW); and
- composting.

The assumptions used to develop energy estimates for each of these activities are briefly described in this section, and examined in detail in appendix C. Results of the analysis are presented by activity in section 4.3.

4.2.1 Energy Expended on Waste Collection

Energy estimates for collecting residential, IC&I and C&D waste were based on an average case developed for collecting residential waste. It was assumed that diesel fuel was used for all collection vehicles, and that each litre of diesel fuel creates 2.73 kg of carbon dioxide equivalents (derived from Jacques, 1992). The assumptions for residential waste collection were:

- truck capacity of 21 m^3;
- 13.5 tonnes daily collection per truck;
- compaction ratio of 3:1;
- medium density suburban route;
- diesel consumption of 78 litres per 100 km;
- daily fuel consumption of 58 litres;
- fuel allocation of 4.3 litres per tonne of waste collected;
- energy input of 167 MJ/tonne of waste collected; and
- carbon dioxide emissions of 11.8 kg/tonne of waste collected.

Energy estimates for collecting residential, IC&I and C&D waste for recycling were based on an average case developed for collecting residential recyclables, which assumed:

- truck capacity of 11 m^3;
- 3.1 tonnes daily collection per truck;
- no on-truck compaction;

- medium density suburban route;
- diesel consumption of 47 litres per 100 km;
- daily fuel consumption of 38 litres;
- fuel allocation of 12.3 litres per tonne of recyclables collected;
- energy input of 475 MJ/tonne of recyclables collected; and
- carbon dioxide emissions of 33.6 kg/tonne of recyclables collected.

Collecting recyclables expends more energy than collecting garbage due to the increased time required per stop to separate the recyclables at the curb and to the lower quantity of materials collected per household compared with garbage collection.

It was assumed that collecting IC&I waste and recyclables would be somewhat more efficient than collecting residential waste and recyclables, with larger loads dispersed over greater distances. Collection rates of 5 tonnes/km for IC&I waste, compared to 4.5 tonnes/km for residential waste (used in a similar GVRD 1993 analysis), were used in this study. The same ratio was also applied to assumptions on collecting IC&I recyclables.

Construction and demolition waste collection was assumed to consist of larger, non-compacted loads that are directly hauled to local sites. Energy input and carbon dioxide emissions for both waste and recyclables collection were set at 50% of residential rates for garbage collection, based on discussions with private sector waste managers.

The energy consumption and greenhouse gas emission rates assumed for collecting residential, IC&I and C&D wastes for both recycling and disposal are in table 4.1.

4.2.2 *Waste Transfer*

Energy expended on waste transfer was estimated using the following assumptions:

- the source of electrical power was assumed to be the national blend, which produces 94,424 kilotonnes of carbon dioxide emissions, creating 1,772 PJ (petajoules) of energy (Environment Canada, 1994). This translates to 0.05 kg carbon dioxide per MJ of electrical energy.
- 40% of residential and IC&I waste is shipped to the final destination through transfer stations, and 6% is directly hauled to the final destination.
- Transfer of C&D waste was not considered in the estimates.
- Transfer operations require 58 MJ/tonne (48.4 MJ/tonne for transportation and 9.6 MJ/tonne for processing).
- Diesel fuel input for transfer operations (transportation and processing) is 1.25 L/t.
- Carbon dioxide emissions from transfer operations are 3.71 kg/tonne (3.42 kg/tonne for transportation and 0.29 kg/tonne for processing).

4.2.3 *Landfilling, Recycling, and Composting*

Energy consumption of 10.5 MJ/tonne of garbage disposed of in landfills, and carbon dioxide emissions of 0.7 kg/tonne of garbage disposed of were used for the analysis. These values correspond to the energy expended during landfill operations such as movement of waste and compaction and covering activities. These values were based on information obtained through an assessment at the Vancouver landfill.

An energy input of 100 MJ/tonne was used for recycling operations. This was calculated using data from a Tellus Institute study, which identified energy consumption values ranging from 88 MJ/tonne for manual recycling operations to 154 MJ/tonne for highly mechanized recycling operations.

Energy usage at composting operations was assumed to be in the 20 to 40 MJ/tonne range. Backyard composting was assumed to require no energy inputs.

Table 4.1 Energy input and greenhouse gas emissions for waste and recyclables collection in Canada, 1992

Waste Source	Energy Input (MJ/tonne collected)		Greenhouse Gas Emissions (kg CO_2/tonne collected)	
	Waste	Recycling	Waste	Recycling
Residential	167	475	11.88	33.60
IC&I	186	186	13.20	13.20
C&D	84	84	5.94	5.94

4.2.4 Energy-from-waste

Energy-from-waste (EFW) facilities incinerate solid waste and produce energy in the form of either steam or electricity. Facilities producing steam generate from 9,000 to 11,000 kg/hr for each burner unit. Facilities generating electricity produce about 2.2 MW electricity per burner unit. Each burner unit takes 100 to 110 tonnes of waste per day. Energy conversion varies from 30 to 34% efficiency in conversion to electricity and can get up to 62% for steam production. Much higher efficiencies are possible for cogeneration scenarios, which may achieve 80% conversion efficiency. For the purpose of this analysis, a 50% conversion efficiency was assumed. Gross and net energy production by EFW plants is:

- energy content of waste sent to combustion (10,458 kJ/kg);
- total waste sent to combustion in Canada (1,198,000 tonnes);
- potential energy in waste (12,529,000 GJ);
- conversion efficiency to output energy (50%);*
- gross energy produced (6,265,000 GJ);*
- energy consumed in waste collection and transfer (167,000 GJ); and
- net energy produced (6,098,000 GJ).

*This includes energy consumed in the operation of the EFWs.

Energy used in collection and preparation of combustible waste is less than 4% of the gross energy recovered in EFW facilities.

4.3 Estimate of Energy Expended on Solid Waste Management

Energy input factors developed for nine different aspects of solid waste management are in figure 4.1. Six of the factors are different waste collection rates for collecting garbage and recyclables in the residential, IC&I and C&D sectors.

- Collection is defined for pickup of waste materials from generators and direct transportation to a landfill, transfer, EFW, or recovery facility.
- Transfer energy input is expended in material handling, reloading and transportation to a landfill, EFW or recovery facility. The energy applied to material handling in EFW facilities has been assumed to be the same as the transfer energy.
- Recovery is the energy applied to sort, handle and reload materials at a recycling depot or facility. This input does not include transportation outside the waste management sector to end-users of the recovered materials.
- Landfill energy input is provided from equipment used for material management and for management of soil for cover soil in a landfill facility.

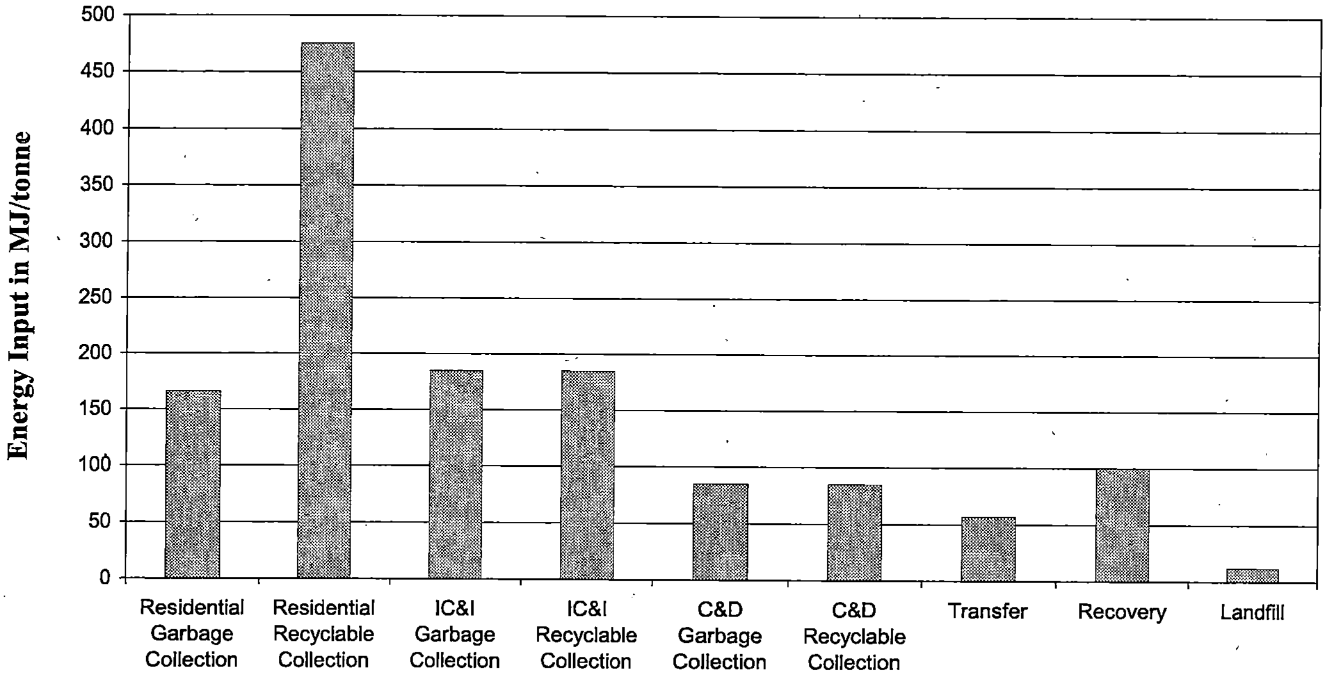

Figure 4.1 Energy input factors for solid waste management activities

Table 4.2 Estimated energy input and carbon dioxide emissions for waste collection and processing in Canada, 1992

Waste Source	Combusted	Composted	Recycled	Landfilled	Total
			Energy Inputs (gigajoules)		
Residential	121,776	27,826	499,091	1,750,020	2,398,713
IC&I	45,257	27,866	1,013,044	1,934,234	3,020,401
C&D	–	–	728,199	429,214	1,157,413
Total	**167,033**	**55,692**	**2,240,334**	**4,113,468**	**6,576,527**
			CO_2 Emissions (kilotonnes)		
Residential	9	5	34	122	170
IC&I	3	1	52	135	191
C&D	–	–	35	30	65
Total	**12**	**6**	**121**	**287**	**426**

Kilotonnes (KT) (tonnes x 10^3)
Kilojoules (KJ) (Joule x 10^3)
Megajoules (MJ) (Joule x 10^6)
Gigajoules (GJ) (Joule x 10^9)
Terajoules (TJ) (Joule x 10^{12})
Petajoules (PJ) (Joule x 10^{15})

Energy input and emissions relate to inputs to the waste collection and processing operations and do not include emissions inherent in the operations such as landfill gas, incinerator emissions and composting emissions.

- Process energy and emissions such as landfill gas, composting and EFW emissions are not considered in this analysis.

The energy input rates for solid waste management activities are presented in figure 4.1.

The percentages of energy use are illustrated in figure 4.2.

4.4 Energy Savings from Recycling Solid Waste in Canada

The estimates of energy required within the waste management sector for the collection and processing of solid waste are in section 4.3. The energy that is captured in EFW facilities is also described and provides a substantial benefit, considering the industry's net energy position. In a similar manner, the flows of energy related to waste recycling need to be considered both from within the waste management industry as well as in the manufacturing sectors where the wastes are reintroduced into products. Within the waste management sector, the total Canadian input of 2.2 PJ of energy for the collection and processing of recyclables as well as the emission of 349 kilotonnes of carbon dioxide is found in table 4.2. The energy input to recycling is 34% of the total input to the waste management industry and, with the rapid expansion of recycling programs, is increasing.

However, when considered in the context of the reintroduction of recyclables into products in place of virgin feedstock, the energy dimension of recycling provides a very different perspective. There are huge potential reductions of energy available to many industries which can use a proportion of recycled material in place of virgin raw materials. The energy savings accruing for common recyclables are presented in table 4.3. The savings are substantial and are attributed to lower energy requirements in the industries recycling the wastes as opposed to the waste management industry. As an example, the 1.3 million tonnes of auto hulks recycled annually would save 4.1 PJ of energy compared to using virgin material, a total which alone exceeds the total energy requirement for the collection and processing of recyclables within the waste management industry. The full energy input into the Canadian solid waste management program is equalled by the recovery and recycling of only 9,800 tonnes of aluminum.

It is estimated that the maximum potential energy saving that could be achieved in Canada by using the recyclable wastes in the current

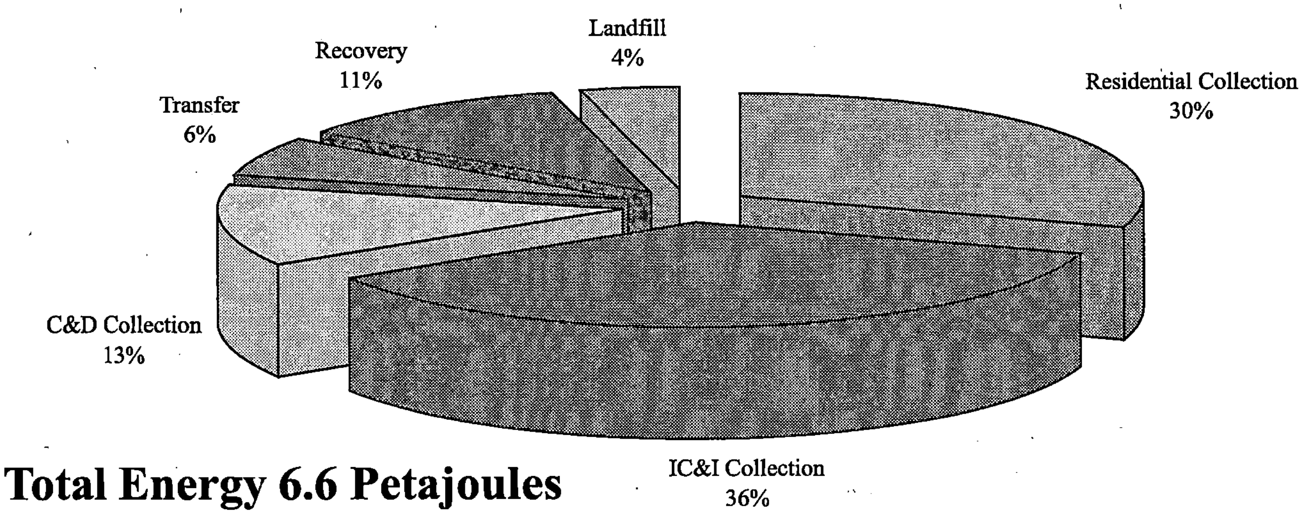

Figure 4.2 Summary of annual energy inputs for solid waste management

waste stream is 300 PJ per annum at 1992 waste generation levels (considering only paper, steel and aluminum). At current diversion levels, savings are estimated at 64 PJ per year or 21% of the potential energy savings. There are also expected to be large savings of energy from recycling plastics, but these recovery systems are quite new and no studies were found with energy saving estimates. Detailed estimates are in appendix C.

Even at the present levels of diversion and recovery into new products, there is an order of magnitude more of energy saved from using recycled products than of energy consumed by the entire solid waste management sector. The energy savings attributed to recycling diverted materials are not necessarily saved by Canadian manufacturers (there is substantial import/export activity in recyclable materials).

4.5 Energy Recovered from Solid Waste in Canada

Energy is recovered from solid waste in Canada through EFW combustion facilities or landfill gas recovery projects. In section 4.2.4, an estimate was provided for EFW operation at 6.3 PJ gross energy output or 6.1 PJ net energy output after operating inputs are deducted. The energy produced by the 10 EFW facilities operating in Canada was generated from 1.2 million tonnes of waste with the output usually in the form of steam (1,673,000 tonnes) in 1992.

In 1994, there were 24 landfill gas recovery projects operating in Canada. These operations recovered 238,000 tonnes of methane (based on a 1994 study by Hickling and Emcon), and about 80% of the methane was used to generate electricity. Total energy generation capacity was 102 MW. In comparable terms, this

Table 4.3 Production energy requirements for virgin versus secondary materials

Component	Virgin Material (kjoules/kg)	Recycled Material (kjoules/kg)	Examples
Bleached kraft paperboard	89808		cartons for milk & frozen food, cosmetics, blister packs
Unbleached coated boxboard	71321	40483	cereal/cracker boxes, beverage carriers, dry soap containers
Linerboard	73552	41203	facing material of a corrugated cardboard container or in solid fibre boxes
Corrugating medium	55274	40111	middle, fluted layer in corrugated cardboard containers
Unbleached kraft paper	73552		bags, shipping sacks, wrapping paper
Aluminum	241688	9668	
Glass	15686	11503	
Steel	22774	19637	

Note: Energy values for fibres are based on bone-dry material represents an annual energy recovery of 2.9 petajoules from these facilities. These projects take advantage of the methane generated from anaerobic decomposition in the landfills and have a finite life, as energy production ceases when all of the waste in the landfill has stabilized.

4.6 Recoverable Energy Content of Waste Disposed of in Canada

Approximately 22.3 million tonnes of waste were discarded (landfilled or sent to incinerators without energy recovery) in 1992 (section 2). This waste contained an energy value which was not exploited at the time. The energy value of the waste was estimated at 267,000 terajoules (TJ) (table 4.4).

Most of the waste disposed of in Canada in 1992 was sent to landfills (96%) that may or may not contain landfill gas recovery systems. Only 24 out of a reported 113 landfills throughout Canada have reported in 1994 the installation of gas recovery systems (section 3). A smaller component of the waste (4 to 5%) was

Table 4.4 Estimated recoverable energy content of discarded waste stream

Material	Energy Content of Landfilled Waste (TJ)	Energy Content of Incinerated Waste (in facilities without energy recovery) (TJ)	Total Energy Content of Discarded Waste (TJ)
Paper			
— newsprint	21,267	201	21,468
— magazines	210	4	213
— cardboard	15,939	81	16,021
— mixed paper	67,164	348	67,512
Plastic			
— high-density polyethylene	3,557	19	3,575
— low-density polyethylene	1	<1	1
— polyethylene terephthalate	362	2	365
— polyvinyl chloroid	–	–	–
— polystyrene	–	–	–
— polypropylene	–	–	–
— mixed plastics	38,593	226	38,815
Organics			
— food waste	58,369	416	58,785
— yard waste	26,745	174	26,919
— mixed organics	2,031	9	2,040
Wood Waste	29,658	68	29,727
Tires	746		746
Textiles	997	5	1003
Total	**265,636**	**1554**	**267,190**

Note: This estimate is based on the estimated composition of the waste discarded in 1992 (see chapter 2 and appendix A), and assumed energy values of various waste stream components which are discussed in appendix C.

The energy content of wastes disposed of in landfill totals approximately 266,000 TJ. The energy content of wastes disposed of in incinerators without energy recovery totals approximately 1,600 TJ.

sent in 1992 to incinerators with or without energy generation capabilities. Most of the waste sent for incineration was burned in energy from waste facilities (approximately 91%) to extract the energy value in the waste and convert it to a useful resource.

The wastes diverted through recycling and composting programs have not been included in this analysis since they are recovered for other purposes.

4.7 *Conclusions on Energy Usage for Solid Waste Management*

Nationally, the scale of energy consumed on waste management in Canada is very small, with total energy inputs of 6.6 PJ, or only 0.07% of primary energy demand in Canada (9,108 PJ in 1991) (Canada's National Report on Climate Change, 1994). The transportation component of the waste management system, which represents 79% of the total sector energy requirement, is very small in the national context at 5.6 PJ, or 0.32% of the national transportation sector demand of 1,742 PJ.

Energy requirements for waste management are expected to grow significantly as we move from the present level of diversion to the national targets, unless collection systems are modified to reduce energy consumption. Collecting recyclables by current methods uses about three times as much energy as collecting garbage on a unit tonnage basis.

Collecting recyclables greatly increases energy consumption for waste management, but this increase is significantly lower than the amount of energy saved by the introduction of recycled material into basic production processes. There are very large energy benefits from recycling steel, aluminum and paper, with lower net positive energy contributions from recycling plastic and glass. The energy benefits do not accrue to the sector collecting the recyclable material but could be an important factor in meeting national energy reduction and greenhouse gas emission targets.

A full accounting of energy consumption and recovery in place in Canada is presented below. Currently, there are 6.6 PJ energy used in the waste management sector and 8.1 PJ recovered through EFW and landfill gas recovery. This places the sector in a net positive position even before considering the 64 PJ that are currently recovered on other industrial sectors through the substitution of recycled for virgin feedstock.

Energy Input to Solid Waste Management

Waste and Recyclables Collection	-5.19 PJ
Transfer (including EFW handling)	-0.43 PJ
Landfill Operation	-0.23 PJ
Recyclables Processing and Composting	-0.73 PJ
Total	**-6.58 PJ**
Gross Energy Produced by EFW Facilities	**6.30 PJ**
Gross Energy Produced by Landfill Gas Recovery	**2.90 PJ**
Energy Saved by Using Recycled Feedstock	**64.00 PJ**
Net Energy Flow from Waste Management and Recycling	**66.62 PJ**

The largest energy source for waste management is refined petroleum products, dominated by the use of diesel fuel for most waste collection and transportation activities.

Studies have suggested that there may be some alteration in the heat value of waste directed to incineration as reduction, source separation, composting and recycling increases; however the operators of Canadian incineration facilities have reported that diversion has not resulted in any dramatic changes in the heating value of waste bound for combustion. Since larger scale diversion may result in changing heating values for these wastes, it will be important to monitor the impact of increased diversion on the heating value of combustible waste. This issue is being considered as part of the Waste Watch Project in Prince Edward Island.

A positive energy contribution can be made if the collection frequencies or collection methods for both garbage and recyclables are altered. This will increase the per-household collection volumes per trip. This will be important for garbage collection, which is on a trend to higher energy use as higher quantities are diverted. At the same time, recyclable collection starts from a high unit collection energy (using current collection methods) and would benefit from larger unit collection volumes. Improvements in this area will help reduce greenhouse gas emissions, which are on an upward curve as recycling increases.

Although the data used and the assumptions made to develop energy input estimates for the waste management sector are appropriate for the strategic level of this study, there is a need to collect more data and to develop some standardized data collection criteria for tracking future system changes and to provide a better basis for program evaluation. Data collection will be made more difficult by the proprietary nature of much of the information from private sector operators, and provisions for data security and aggregation of reports will be needed.

4.8 References

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Appendix A

Waste Quantity and Composition Estimates

Estimates of the quantities and composition of waste managed by different methods in each of the provinces and territories, and a summary of the estimates for Canada, are in this appendix.

These estimates were intended to be used in the Perspectives on Solid Waste Management project to identify target areas for waste diversion efforts and potential opportunities for research and commercialization of alternative technologies to handle waste. The methodology applied is appropriate for the broad perspective of this project. These estimates are based on data from published sources and do not represent detailed, comprehensive estimates of each waste stream and material category.

1 *Information Used for Analysis*

The estimates developed in this report on the quantities of materials generated, diverted and disposed of in each province/territory in 1992 were based primarily on information provided to Environment Canada by provincial agencies for the CCME National Solid Waste Inventory. Additional sources of data were used to break the provincial estimates down to a greater level of detail. These included waste composition studies carried out in various Canadian communities and neighbouring regions or provinces where the waste composition was considered similar. Additional information on specific issues (such as the amount of waste combusted nationally) was obtained from a number of Environment Canada reports and in-house files. A list of the waste composition studies and other sources used to develop the estimates is contained in the references at the end of this appendix. Specific information used for each province/territory will be noted in the discussion of the estimates for the relevant province/territory in sections 3.2 to 3.13.

2 *Approach Used to Develop Waste Quantity and Composition Estimates*

Waste generation estimates reported in other published literature may differ from those presented in this report. The various estimates in other reports and published data are based on different approaches, sources and methodologies, and yield different results. Differing composition estimates have some effect on estimates of energy content of waste but do not significantly affect economic analyses.

The approach used to estimate the quantity and composition of waste managed in each province varied, because of the quality of existing data and the sources which were considered most appropriate for extrapolations. The approach used for each province/territory is described in more detail in sections 3.2 to 3.13.

Estimates of the quantities of solid waste generated, diverted, combusted and landfilled from the residential, IC&I and C&D sectors have been developed. The meaning adopted for these categories is in line with the concepts used in the National Solid Waste Tracking System. Brief descriptions of these terms follow:

Solid waste: any material for which the generator has no further use and which is discarded at waste disposal, recycling or composting facilities. This excludes wastes that are associated with primary resource extraction or agricultural harvesting, conventional air pollutants and liquid effluents discharged from manufacturing sites, waste sludges from sewage treatment, soil from contaminated sites cleanup, and nuclear and hazardous wastes.

Diversion: recycling or composting (backyard or central facilities) of solid waste materials which otherwise would be disposed of at landfills or incinerator facilities. In assessing the information provided by the provinces to Environment Canada, material reported recycled was considered marketed.

Combusted: the gasification of solid waste materials in incinerators (whether or not facilities are designed for energy recovery). The combustion process results in the generation of an ash/residue mixture, which is considered to contain fly ash, bottom ash and non-combustible materials for the purpose of this analysis. Material considered combusted does not include the ash/residue. The material sent for combustion would include both gasified material and ash/residue.

Landfilled: the disposal of solid waste materials in municipal landfills and some private landfills.

Residential sector: solid waste material generated, diverted or disposed from residential dwellings, including multi-unit dwellings.

IC&I sector: solid waste material generated, diverted or disposed of from institutional, commercial and industrial establishments such as manufacturing, transportation, retail, wholesale and warehousing, commercial (e.g., restaurants and banks) and non-commercial (e.g., health and education) services. The by-products of primary resource extraction and agricultural harvesting are not included.

C&D sector: solid waste material from residential and commercial low-rise construction, residential high-rise construction, commercial construction, renovation, demolition and land-clearing. Also, road and bridge construction waste (concrete and asphalt) is included although it is often not considered part of the municipal solid waste stream.

In general the following estimates were developed:

- Estimates of the quantity and composition of waste generated, diverted, combusted and landfilled were developed for each province/ territory using a variety of sources and methods. The provincial/territorial estimates were added together to develop national estimates for Canada.
- Depending on the data available, either waste generation or waste disposal data were used as the starting point for provincial waste quantity estimates.
- Where waste generation data were used, data on waste recycled, composted and combusted were subtracted from generated values to estimate the waste disposed.
- Where waste disposal data were used as the starting point of the estimates, data on waste recycled and composted were added to the disposed values (combusted and landfilled) in order to estimate the waste generated.
- Data on waste recycled, composted and combusted were obtained from provincial sources, Environment Canada and a number of published and unpublished reports. Where information was not available at the detailed composition level required for the analysis, a number of assumptions were used to develop a preliminary estimate of the parameter required. These assumptions can be refined in future estimates, when better data become available.
- When the quantities of waste managed by each method were identified, an effort was made to separate the quantities into three major generating sources: residential, IC&I and C&D.
- Available waste composition studies were used to estimate the quantities of different materials in each waste stream (residential, IC&I and C&D).

Estimates of the quantities of waste generated, diverted, combusted and landfilled were developed for each province and territory. These estimates were then totaled to provide national estimates of the waste flow.

The following general assumptions and data sources were used.

Population

Population estimates were taken from provincial/territorial data and conform to the summary table reporting waste disposal provided by Environment Canada (National Solid Waste Inventory) for all provinces/territories (Note: For Nova Scotia, more detailed data were used (see section 3.12 Nova Scotia estimates).)

Material Categories

The material categories used are based on the National Solid Waste Tracking System. Some categories have been omitted as the quantities were considered either not relevant to this study or insignificant, or data were not available or were insufficiently detailed to make appropriate estimates. Examples of the waste materials included in these categories are documented in the National Solid Waste Tracking System Reference Document (Environment Canada, 1992). Some material categories that are not typically considered part of the solid waste stream as they are not typically disposed of in municipal landfills—such as auto wrecks and road and bridge construction waste—have been included in this analysis.

Combustion

Estimates of waste combusted and ash disposed of are very limited. They were based primarily on data provided to Environment Canada as part of the CCME work on the National Solid Waste Inventory and on data provided in the 1994 survey of incineration facilities (Environment Canada, 1994). This summary provided a list of incinerator facilities in Canada, including their rated capacity and some data on the actual quantities combusted in these facilities in 1993. The list was subsequently updated using additional data provided by Environment Canada (Environment Canada, 1994b). The data in the summary have been supplemented with information on incineration included in other published literature (such as waste audits).

When the actual 1992 throughput for a particular incinerator was not available, the throughput was assumed to be 80% of the reported rated capacity. In the absence of data specifying the source of waste combusted, it was assumed to be primarily residential waste (80%), with the balance being IC&I waste (20%). While some C&D wastes (such as wood) are also likely combusted at some facilities, little data was available on the C&D stream. Therefore no C&D waste were considered to be combusted for the purposes of this analysis.

A list of the incinerators considered in this analysis and the assumed throughput in 1992 is presented in table A-1.

It was further assumed that the composition of the waste sent for combustion was essentially the same as that estimated to be landfilled—the generated waste stream less diversion, for both residential and IC&I streams. (Note: Ash and residue resulting from combustion, which is included in the landfilled stream, were excluded for this purpose.) Also, some materials such as white goods were excluded from the combustion stream, as they would be separated from the incinerator feed.

In general, reported quantities of waste disposed of at incinerator facilities were assumed to represent feed to the incinerator. Estimates of the waste gasified during combustion and of the ash produced were made. A general factor of 30% of the waste sent for incineration was assumed to require landfilling as ash/residue unless more detailed data were available. The ash from the incinerators is primarily residue from the bottom of the incinerators and some ash recovered from the flue gas (fly ash). It may contain incombustibles such as glass and metal depending on the operation of the incinerator. At some facilities, some incombustibles may be recovered for recycling. However, since no data were available, no recovery of recyclables from

Table A-1 Summary of incinerators and energy from waste facilities in Canada, 1992

Facility	Throughput assumed (tonnes/yr)	EFW or non-EFW	Source
British Columbia			
Burnaby EFW Facility	235,000	EFW	1994 summary
Cowichan Valley	11,250	non-EFW	1994 summary
Tumbler Ridge	3,750	non-EFW	1994 summary
Ladysmith	3,750	non-EFW	1994 summary
Lake Cowichan	3,750	non-EFW	1994 summary
Subtotal	**257,500**		
Ontario			
Victoria Hospital	30,000	EFW	1994 summary
Solid Waste Reductin Unit (SWARU)	98,700	EFW	1994 summary
General Motors (GM)	7,200	EFW	1994 summary
Peel Resource Recovery	133,000	EFW	1994 summary
3M Canada	8,000	EFW	
Subtotal	**276,900**		
Quebec			
Quebec Urban Community EFW	226,066	EFW	Province
Levis Incinerator	24,085	non-EFW	Province
Montreal Des Carrières	291,278	EFW	Province
Subtotal	**541,429**		
Prince Edward Island			
PEI Energy Corps	29,843	EFW	Province/1994 summary
Subtotal	**29,843**		
Nova Scotia			
Graywood, Annapolis City &		non-EFW	NS waste audit reports
Crisp Road, Annapolis City	6,828	non-EFW	NS waste audit reports
Cape Breton County, Sydney	27,730	EFW	NS waste audit Reports
West Green, Shelburne	1,476	non-EFW	NS waste audit reports
Lunenburg (2)	11,350	non-EFW	NS waste audit reports
Advocate, Cumberland City	7,821	non-EFW	NS waste audit reports
Gegogan Road, St. Mary's	1,500	non-EFW	NS waste audit reports
Subtotal	**56,705**		
Newfoundland			
Holyrood &		non-EFW	St. John's waste audit
Conception Bay South	25,916	non-EFW	St. John's waste audit
Harbour Grace	6,400	non-EFW	1994 summary
Labrador City	3,200	non-EFW	1994 summary
Subtotal	**35,516**		
Total	**1,197,893**		

	Throughput (tonnes)	Percent of Total
All Incinerators	1,197,893	100%
EFW Facilities	1,086,817	91%
Non-EFW Facilities	111,076	9%

Notes:
1. Refer to section 4.8 for detailed references.
2. For non-EFW facilities data taken from 1994 summary, 80% of rated throughput reported was assumed (except for B.C.).
3. For non-EFW facilities in B.C., rated throughput reported was used.
4. For EFW facilities data taken from 1994 Summary, actual 1993 throughput reported was used.
5. For EFW facilities taken from database, actual 1992 throughput reported was used.
6. Refer to section A.2 for details on calculations for incinerated materials.

combustion residue was considered in this analysis.

All of the ash/residue is reported as inorganic material in the "landfilled" column, including the quantities of glass, metal, etc. that remain in the residue. Therefore a portion of each material estimated to be in the feed stream to incinerators has been allocated to the ash/residue category. For this reason, for Canada and the provinces that have incinerators, the total quantities landfilled, sent for combustion, composted and recycled do not equal the quantity of each material generated; some of the material has been added to the ash/residue category in the landfilled column.

Composting

The number of backyard composters distributed to homeowners in each province/territory was obtained. It was assumed that 80% of these are used effectively, based on studies of composter use in Ontario (Centre and South Hastings Waste Management Board, 1994; Compost Management Assoc., 1990, 1993; Rivers, 1994). This total was multiplied by a diversion rate of 169 kg/composter/year to estimate the quantity of organics diverted from residential sources (MOEE, 1994).

Data on centralized composting sites and their capacities were obtained from a 1993 report by the Composting Council of Canada. Additional data from SENES Consultants on the composting sites were incorporated. Actual quantities of waste composted in each province were also reported by many provincial sources.

Organic material diverted through backyard composters generally was assumed to consist of 33% leaf/yard waste and 67% food waste, based on studies conducted in Ontario (Centre and South Hastings Waste Management Board, 1994; Compost Management Ass., 1990, 1993; Rivers, 1994). While this proportion is expected to vary across the provinces and according to other physical/ demographic characteristics of the location, this is considered a reasonable estimate for this analysis due to the relatively small portion of the overall waste stream represented by this component. Where more specific data were available, they were adopted.

Recycling Rates

Estimates of the quantities of material recycled from residential and IC&I sources were based primarily on data provided to Environment Canada by the provinces as part of the ongoing work on the National Solid Waste Inventory. These data were supplemented, where necessary, with information from published documents. Quantitative information on recycling activities is quite limited. Estimates of the composition of the recycled stream were made based on the data provided to Environment Canada by the provinces/territories. In some cases, assumptions were made regarding the source and composition of recycled waste. These assumptions are noted in the discussion of estimates for each province/ territory.

C&D Waste

The data provided by the provinces in many cases did not appear to include some components of the C&D waste stream such as road and bridge construction waste. (This is typically not considered part of the municipal solid waste stream.) Additional data on C&D waste quantities, composition, recycling and disposal for each province were obtained from the SENES (1993) report on C&D waste as well as from other published documents. In some cases, data on a specific region or province were considered more reliable than the SENES data and therefore were used.

Other Wastes

Auto hulks were generally not included in the data provided by provinces—they are not generally managed as part of the municipal waste stream. However, as they are included in the National Solid Waste Tracking System, very approximate provincial estimates for these have been included. The estimates are based on per-capita generation estimates for major regions in Canada. These estimates have been taken from published data.

In some cases, white goods appear to be included in the data on waste generation or disposal provided by the provinces. Where they appear not to be included, very approximate estimates have been made based on information from other published data. Some municipalities have programs for handling white goods, but data are limited on the management of white goods nationally, and therefore estimates are considered very uncertain.

Similarly, data on the management of tires are very limited. Tires appear to be included in some provincial data. Where they appear not to be included, approximate estimates have been incorporated based on other published sources.

3 *Estimates for Each Province/ Territory and Canada*

3.1 *Canada*

The following summarizes the population and the estimated quantity and composition of waste generated, recycled, incinerated and landfilled in Canada in 1992.

- Population of Canada was 26,997,401.
- An estimated 33.2 million tonnes of waste were generated consisting of:
  - 10.5 million tonnes of residential waste,
  - 12.7 million tonnes of IC&I waste, and
  - 10.0 million tonnes of C&D waste.
- This represents a per-capita generation rate of 1.23 tonnes/cap./yr.
- An estimated 10.3 million tonnes of waste was diverted consisting of:
  - 1.2 million tonnes from residential sources,
  - 3.6 million tonnes from IC&I sources, and
  - 5.4 million tonnes of C&D material.
- An estimated 1.2 million tonnes of waste were sent for combustion. Of this:
  - 1.1 million tonnes went to EFW facilities, and
  - 111,000 tonnes went to facilities without energy recovery.
- An estimated 341,000 tonnes of ash/residue were generated during combustion.
- An estimated 22.1 million tonnes of waste were landfilled consisting of:
  - 8.7 million tonnes from residential sources,
  - 8.8 million tonnes from IC&I sources, and
  - 4.5 million tonnes of C&D material.

Estimates of waste generation, diversion, combustion and disposal in landfill for Canada were derived by summing provincial/territorial estimates. The approach and details of the estimates and sources of information are described by province and territory (sections 3.2 to 3.13).

3.2 *British Columbia*

The following summarizes the population and the estimated quantity and composition of solid waste generated, diverted, combusted and landfilled in British Columbia.

- Population of British Columbia was approximately 3,371,000.
- An estimated 4,025,000 tonnes of waste were generated consisting of:
  - 1,268,000 tonnes of residential waste,
  - 1,440,000 tonnes of IC&I waste, and
  - 1,318,000 tonnes of C&D Demolition Land Clearing (DLC) waste.

- This represents a per-capita generation rate of 1.19 tonnes/cap/yr.
- An estimated 1,062,000 tonnes of waste was diverted consisting of:
  - 142,000 tonnes from residential sources,
  - 412,000 tonnes from IC&I sources, and
  - 508,000 tonnes of C&D material.
- An estimated 258,000 tonnes of waste were sent for combustion. Of this:
  - 235,000 tonnes went to EFW facilities, and
  - 23,000 tonnes went to facilities without energy recovery.
- An estimated 59,000 tonnes of ash/residue were generated during combustion.
- An estimated 2,765,000 tonnes of waste were landfilled consisting of:
  - 1,003,000 tonnes from residential sources,
  - 952,000 tonnes from IC&I sources, and
  - 810,000 tonnes was C&D material.

Estimates have been based on waste generation, disposal and recycling data in two tables provided to Environment Canada by the B.C. Environment Department for the National Solid Waste Inventory (NSWI). Also, additional data on C&D waste generation and on composting and recycling were incorporated from other sources (SENES, 1993; SENES, 1993a; Composting Council of Canada, 1993; RIS, 1993; Environment Canada, 1994).

Disposal data in the two tables provided by B.C. Environment were used to determine overall waste disposal for that province. However, the "waste in", "waste recycled" and "residual management" figures were modified as follows:

- Composting data from other sources were used instead of quantities reported on the tables:
  - A total of 36,397 tonnes of organics was composted (SENES, 1993; Composting Council of Canada, 1994; RIS, 1993) and was substituted for the organics waste (food, yard and other) amount reported in the tables as generated and recycled.

  - 8338 tonnes;
  - 671 tonnes;
  - 6251 tonnes;
  - 481 tonnes;
  - 40 tonnes;
  - 151.7 tonnes generated; and
  - Total of 15,675.7 tonnes recycled.
- Data on waste categories not included in this analysis were subtracted from totals:
  - Household Hazardous Waste (HHW) and biosolids - 435 tonnes generated;
  - "Residential," 19,259.7 tonnes generated;
  - "IC&I," 247 and 33 tonnes generated;
  - "DLC", a total of 3,701.8 tonnes generated;
  - "Source Not Identified"; and
  - Total of 23,665.5 tonnes recycled.
- The differences between the two tables were reconciled as follows:
  - C&D data were taken from Sheet B (Sheet A appeared in the B.C. December, 1993 summary report).
  - For each material, the highest figure for recycling on the tables was adopted.

The revised totals were:

- 381,126.6 tonnes residential "waste in";
- 427,791.1 tonnes IC&I "waste in";
- 1,022,967 tonnes of C&D "waste in";
- 2,193,834.5 tonnes of source not identified "waste in";

- 1,062,434.5 tonnes recycled; and,
- 2,963,251.7 tonnes of residual.

The total waste disposed of (the data from B.C. Environment modified as described above) was then split between residential, IC&I and C&D streams according to estimates in a waste audit conducted for the Greater Vancouver Regional District (GVRD) (RIS, 1993). That study estimated the sources of waste to be 38% residential, 34.7% IC&I and 27.3% C&D. That estimate did not include auto hulks, so the reported data for these were excluded from the allocation process and then added to the IC&I stream total.

The quantities reported by B.C. Environment were assumed to include the quantities of waste combusted. Data on the quantities combusted were taken from a 1994 summary of active municipal solid waste (MSW) incineration facilities in Canada (Environment Canada, 1994). This indicated five MSW facilities operating in B.C. in 1992. Throughput was estimated as the rated capacity reported for the four small facilities, while the reported actual throughput reported for 1993 was used for the Burnaby facility. The source of material sent for combustion was assumed to be 80% residential for the smaller facilities and 60% residential for the Burnaby facility. The balance was assumed to be IC&I waste. (No C&D waste was assumed to be combusted for the purpose of this analysis.) Ash/residue generation was assumed to be 30% of feed for the small facilities, while the reported actual ash/residue generation for the Burnaby facility was used (approximately 23%).

The composition of the landfilled waste streams (not including ash/residue generated during combustion) was defined by the 1993 GVRD waste audit report (RIS, 1993). The feed to incinerators was also assumed to have this composition. For the landfilled stream, the quantities of materials sent for combustion were subtracted from the total quantity of each material sent for disposal at landfills or incinerators (refer to appendix A, section 2), and ash/residue was added to the landfilled stream.

Data on recycling were taken from the tables provided by B.C. Environment. The two tables were rationalized by adopting the higher of the recycling rates appearing in the two tables for any given material. Therefore, the recycling rates for some materials differ from the quantities reported by Environment Canada as part of the NSWI (Environment Canada, 1994a). The source of recycled materials was estimated according to the estimated proportion of waste generated by each source (residential, IC&I and C&D). Checks were made to ensure that the estimates did not contradict data reported on the tables from B.C. Environment, where sources of recycled materials were indicated.

Data for composting organics (food and yard waste) were taken from other sources and replaced figures from the B.C. Environment data (SENES, 1993; Composting Council of Canada, 1993; RIS, 1993). These data were considered more reliable and comprehensive and indicated a higher composting rate.

Waste generation for each waste stream was then estimated by summing the estimates of waste landfilled, waste sent for combustion and waste diverted. (Note: The materials which are landfilled as part of ash/residue were not included in the inorganic category, because they were included in the respective material categories of waste sent for combustion.)

3.3 Yukon Territory

The following summarizes the population and the estimated quantity and composition of waste generated, diverted, combusted and landfilled in Yukon Territory in 1992.

- Population of Yukon Territory was approximately 28,000.
- An estimated 24,000 tonnes of waste were generated consisting of:
  - 3,000 tonnes of residential waste,

 - 6,000 tonnes of IC&I waste, and
 - 15,000 tonnes of C&D waste.
- This represents a per-capita generation rate of 0.87 tonnes/cap/yr.
- An estimated 7,000 tonnes of waste was diverted consisting of:
 - 200 tonnes from residential sources,
 - 1,300 tonnes from IC&I sources, and
 - 5,700 tonnes of C&D material.
- An estimated 17,000 tonnes of waste were landfilled consisting of:
 - 2,800 tonnes from residential sources,
 - 4,800 tonnes from IC&I sources, and
 - 9,600 tonnes was C&D material.
- no waste was combusted.

Detailed published data on waste management in Yukon Territory are very limited. Therefore, the generation and recycling data supplied by the Territory (Paslawski, 1994) to Environment Canada for the NSWI were used as the basis of the waste quantities estimates. These data were supplemented with data from other sources (SENES, 1993; CH2M Hill, 1990; Ontario Ministry of Environment, 1991; M.M. Dillon, 1991). Data from New Brunswick and Newfoundland were also used; refer to sections 3.10 and 3.13 of appendix A.

A first estimate of overall waste generation (18,200 tonnes) was determined by multiplying the per-capita waste generation rate reported by the Territory (0.65 tonnes per capita per year—the same as reported for the Northwest Territories) by the population (28,000).

Total C&D waste generation was assumed to be 15,238 tonnes (SENES, 1993). It was assumed that the overall generation rate determined above included C&D waste but that road- and bridge-related C&D waste of 5,166 tonnes (SENES, 1993) was not included in the estimate. Building-related waste of 10,072 tonnes (SENES, 1993) was subtracted from the total generation estimate of 18,200 tonnes to obtain an estimate for residential and IC&I waste generation (not including auto hulks) of 8,128 tonnes. The waste generated was allocated to the residential and IC&I sectors according to estimates made for Newfoundland (residential accounting for 37% and IC&I accounting for 63% [see section 3.13, appendix A for estimates for Newfoundland]).

It was assumed that the generation rate provided by the Territory (0.65 tonnes per capita per year) included estimates for both white goods and tires, although there is significant uncertainty in this assumption. An estimate for auto hulks generated (1,036 tonnes) was incorporated, based on an estimate of 0.037 tonnes per capita for auto hulks generation in St. John's, Newfoundland. (Newplan Consultants, 1993).

Therefore, total waste generated was estimated to be 24,402 tonnes.

The composition of the residential waste stream was estimated based on waste generation data for New Brunswick provided by the Province of New Brunswick (NBDOE, 1994) because isolated communities having particular waste generation characteristics were assumed to be a major component of both regions. The composition of the IC&I waste stream was derived by subtracting material generation estimates for the residential stream from estimates of the material generation rates for the combined IC&I and residential streams. The composition of the combined waste stream was based on data from a report by M.M. Dillon consultants which reported composition estimates for northern communities. (These data were provided by the Northwest Territories.) The C&D waste stream composition was taken from the SENES report on C&D waste in Canada (SENES, 1993).

Estimates of recycling and composting in Yukon Territory provided by the Territory were adopted. In the absence of data on the source of recycled waste, the figures were allocated equally to each sector except in the case of cardboard, which was attributed entirely to the IC&I sector. It was assumed that all auto hulks were diverted from municipal landfills.

There were no active incinerator facilities in Yukon Territory in 1992.

For each material, the quantity landfilled was derived from the estimated waste generated less the estimated quantities recycled/composted.

3.4 Alberta

The following summarizes the population and the estimated quantity and composition of waste generated, diverted, combusted and landfilled in Alberta in 1992.

- Population of Alberta was approximately 2,565,000.
- An estimated 3,045,000 tonnes of waste were generated consisting of:
  - 654,000 tonnes of residential waste,
  - 1,474,000 tonnes of IC&I waste, and
  - 917,000 tonnes of C&D waste.
- This represents a per-capita generation rate of 1.19 tonnes/cap./yr.
- An estimated 563,000 tonnes of waste was diverted consisting of:
  - 34,000 tonnes from residential sources,
  - 151,000 tonnes from IC&I sources, and
  - 378,000 tonnes of C&D material.
- An estimated 2,483,000 tonnes of waste were landfilled consisting of:
  - 621,000 tonnes from residential sources,
  - 1,323,000 tonnes from IC&I sources, and
  - 539,000 tonnes of C&D material.
- No waste was combusted.

Estimates have been based on waste disposal and recycling data in the table provided to Environment Canada by Alberta Environment for the NSWI. Also, additional data on C&D waste generation, composting and recycling were incorporated from other sources (SENES, 1993; SENES, 1993a; Composting Council of Canada, 1993; Stanley Associates, 1988; B.C. Ministry of Environment, 1991; RIS, 1993; CH2M Hill, 1991).

Disposal data in the tables provided by Alberta Environment were used to determine overall waste disposal in Alberta. However, some material reported disposed of was not relevant to this analysis and was subtracted from the total. This included oil and hazardous waste totalling 13,881 tonnes. The tables report disposal data from communities representing a population of 2,068,628. Using the modified disposal rate (less HHW, etc— 2,002,201 tonnes), the quantity of waste disposed in the province was scaled to the population of 2,565,000. Therefore, the overall waste disposed was estimated to be 2,482,634 tonnes.

The waste disposed was allocated to the residential, IC&I and C&D streams using data from the SENES survey of C&D waste in Canada and the Alberta Environment data. C&D waste was assumed to be included in the Alberta Environment data. For six communities, the Alberta Environment data explicitly indicate the source of the waste. From this data, the average portion attributed to residential sources is 25%, or 620,658 tonnes. Therefore, IC&I and C&D waste were assumed to represent the remaining 75% of waste disposed. The SENES report estimated C&D waste to be 539,186 tonnes in 1992. Therefore the IC&I waste stream was estimated to be 1,322,789 tonnes.

The composition of the landfilled waste streams was determined from other sources. The residential waste stream composition was based on data from a study of Edmonton's waste stream conducted in 1987 and documented in a report on Alberta's recycling industry (Stanley

Associates, 1988). These data were broken out into more material categories according to information from a 1991 study of the GVRD waste stream (RIS, 1993). Also, white goods were not assumed to be represented in the composition reported for Edmonton, so an estimate was incorporated based on an assumption that white goods represent 2.5% of the residential waste stream in Ontario (CH2M Hill, 1991). The IC&I waste composition was based on data from the GVRD study (RIS, 1993). The composition of the C&D waste stream was taken from the SENES report (SENES, 1993).

According to the data available, there were no active incinerators in Alberta in 1992.

Data on recycling were taken from the table provided by Alberta Environment. Data reported for materials not relevant to this analysis have not been included. Milk cartons have been included with mixed paper. Propane tanks have been included with ferrous metal. Approximately 2,260 tonnes of Blue Box materials have been distributed to paper, glass, plastics and metals according to the proportions recovered from other communities.

Data for composting of organics (yard waste—16,013 and 706 tonnes of residential and IC&I waste respectively) were taken from other sources and replaced figures from Alberta Environment (2,284 tonnes) (SENES, 1993; Composting Council of Canada, 1993; RIS, 1993). These data were considered more reliable and comprehensive and indicated a higher composting rate.

Recovery rates of C&D materials were taken from the SENES report (SENES, 1993). The reported recovery of wood (28,095 tonnes) was assumed to include the 1,106 tonnes of wood and trees reported by Alberta Environment. All of the auto hulks were assumed to be diverted.

Therefore the total waste diverted was estimated to be 563,048 tonnes.

Generation for each waste stream was then estimated by summing the estimates of waste landfilled and diverted.

3.5 Saskatchewan

The following summazises the population and the estimated quantity and composition of solid waste generated, diverted, combusted and landfilled in Saskatchewan in 1992.

- Population of Saskatchewan was approximately 994,000.
- An estimated 1,260,000 tonnes of waste were generated consisting of:
  - 438,000 tonnes of residential waste,
  - 462,000 tonnes of IC&I waste, and
  - 360,000 tonnes of C&D waste.
- This represents a per-capita generation rate of 1.27 tonnes/cap./yr.
- An estimated 186,000 tonnes of waste was diverted consisting of:
  - 21,000 tonnes from residential sources,
  - 79,000 tonnes from IC&I sources, and
  - 86,000 tonnes of C&D material.
- An estimated 1,074,000 tonnes of waste were landfilled consisting of:
  - 416,000 tonnes from residential sources,
  - 383,000 tonnes from IC&I sources, and
  - 275,000 tonnes was C&D material.
- No solid waste was combusted.

Estimates have been based on waste disposal and recycling data provided to Environment Canada by Saskatchewan Environment for the NSWI. Also, additional data on residential, IC&I and C&D waste generation and on composting were incorporated from other sources (SENES, 1993; SENES, 1993a; Composting Council of Canada, 1993; B.C. Ministry of Environment, 1991; CH2M Hill, 1990).

An estimated waste generation rate of 1.13 tonnes per capita per year, based on data on quantities of waste landfilled in Regina between 1978 and 1986 (Saskatchewan Environment, 1992) was used as a starting point for the analysis. This generation rate was assumed not to include all C&D waste generated from activities such as road and bridge building. Estimates of C&D waste generation were therefore taken from the SENES report on C&D waste in Canada (SENES, 1993). The total waste generated (less auto hulks and road and bridge construction waste—1,122,881 tonnes) was therefore estimated by multiplying the generation rate (1.13 tonnes per-capita per year) by the provincial population (993,700).

The Saskatchewan Environment estimate of total waste generated (1,122,881 tonnes) was allocated to the residential, IC&I and C&D sectors according to data from a sampling study conducted in Saskatoon. Residential waste accounted for 39% of waste, IC&I for 36%, and the remaining 25% was attributed to the C&D sector. The difference between the SENES estimate of C&D waste generation (360,416 tonnes) and the C&D generation included in the generation rate (280,720 tonnes) was added to the estimate of overall waste generation. An estimate for the generation of auto hulks was added based on a generation rate estimated from Ontario (57,635 tonnes) (CH2M Hill, 1990).

Therefore, the overall waste generated was estimated to be 1,260,211 tonnes: 437,924 tonnes of residential waste, 461,872 tonnes of IC&I waste and 360,416 tonnes of C&D waste (as estimated by SENES, 1993).

The composition of the generated waste streams was defined from other sources. The IC&I waste stream composition was estimated based on a study of three communities in B.C. (B.C. Ministry of Environment, 1991). The IC&I waste stream in Kamloops B.C. was used, because it represents an estimate for a small interior city in B.C. and was therefore considered to be representative of the IC&I sector in the province of Saskatchewan.

The residential waste stream composition was then derived by subtracting estimates for the IC&I waste stream from estimates of the combined residential and IC&I waste stream composition based on data from the Regina study (Saskatchewan Environment, 1992). The composition was assumed not to include white goods, so an estimate was made based on estimated white goods generation in Ontario (2.5% of the residential waste stream) (CH2M Hill, 1991). The composition of the C&D waste stream was taken from the SENES report (SENES, 1993).

Data on recycling were taken from the table provided by Saskatchewan Environment. The materials reported recovered were split equally between the residential and IC&I streams in the absence of detailed information. Data for composting of organics (food and yard waste, totalling 96 tonnes) were taken from the survey conducted by the Composting Council of Canada and SENES (SENES, 1993; Composting Council of Canada, 1993; RIS, 1993). Leaf and yard waste composted was allocated to the residential stream while the material reported to be collected from food banks (Composting Council of Canada, 1993) was allocated to the IC&I sector. C&D waste diversion was taken from the SENES report on C&D waste in Canada (SENES, 1993). All of the auto hulks were assumed to be diverted. Therefore the total waste diverted was estimated to be 186,310 tonnes.

According to the data available, there were no active incinerators in Saskatchewan in 1992.

Waste disposed of in landfills for each waste stream was then estimated by subtracting the estimates of waste diverted from the estimated waste generated.

3.6 *Northwest Territories*

The following summarizes the population and the estimated quantity and composition of solid waste generated, diverted, combusted and landfilled in the Northwest Territories in 1992.

- Population of the Northwest Territories was approximately 56,000.
- An estimated 49,000 tonnes of waste were generated consisting of:
  - 6,000 tonnes of residential waste,
  - 12,000 tonnes of IC&I waste, and
  - 31,000 tonnes of C&D waste.
- This represents a per-capita generation rate of 0.88 tonnes/cap/yr.
- An estimated 14,000 tonnes of waste was diverted consisting of:
  - 50 tonnes from residential sources,
  - 2,200 tonnes from IC&I sources, and
  - 11,600 tonnes of C&D material.
- An estimated 35,000 tonnes of waste were landfilled consisting of:
  - 6,000 tonnes from residential sources,
  - 10,000 tonnes from IC&I sources, and
  - 20,000 tonnes was C&D material.
- No waste was combusted.

Detailed published data on waste management in the Northwest Territories (NWT) are very limited, so the generation and recycling data supplied by the territory (Thompson, 1994) to Environment Canada for the NSWI were used as the basis of the waste quantities estimates. These data were supplemented with data from other sources (SENES, 1993; CH2M Hill, 1990; Ontario Ministry of Environment, 1991; MM Dillon, 1991; Wolnik, 1995). Data from New Brunswick and Newfoundland also have been used (refer to sections 3.10 and 3.13 of appendix A).

A first estimate of overall waste generation of 36,465 tonnes was determined by multiplying the per-capita waste generation rate provided by the NWT from a report on the Coppermine municipal dump by MM Dillon (0.65 tonnes per capita per year) by the population (56,100).

Total C&D waste generation was assumed to be 31,169 tonnes (SENES, 1993). It was assumed that the overall generation rate determined above included C&D waste but that road and bridge-related C&D waste of 10,569 tonnes (SENES, 1993) was not included in the estimate. Information provided by the Department of Renewable Resources indicate that this amount of road and bridge-related waste may be high. However, no additional data were available (Wolnik, 1995). Building-related waste of 20,600 tonnes (SENES, 1993) was subtracted from the total generation estimate of 36,465 tonnes to obtain an estimate for residential and IC&I waste generation (not including auto hulks) of 9,946 tonnes. The waste generated was allocated to the residential and IC&I sectors according to estimates made for Newfoundland, residential accounting for 37% and IC&I accounting for 63% (refer to section 3.13).

It was assumed that the generation rate provided by the NWT (0.65 tonnes per-capita per year) included estimates for both white goods and tires generated, although there is significant uncertainty in this assumption. An estimate for auto hulks generated was incorporated (2,076 tonnes), based on an estimate of 0.037 tonnes per capita for auto hulks generation in St. John's, Newfoundland. (Newplan Consultants, 1993). Additional information provided by the Department of Renewable Resources indicated that an estimated 1,627 auto hulks would have been disposed in 1992 (Wolnik, 1995). Assuming a weight for each vehicle within the range found in Newfoundland, the estimate of 0.037 tonnes per capita compares with the estimate provided by the NWT.

Therefore, total waste generated was estimated to be 49,110 tonnes.

The composition of the residential waste stream was estimated based on waste generation data for New Brunswick provided by the Province of New Brunswick (NBDOE, 1994), because isolated communities having particular waste generation characteristics were assumed to be a major component of both regions. However, based on information provided by the NWT Department of Renewable Resources (Wolnik, 1995), the proportion of yard waste has been reduced by 50%. The composition of the IC&I waste stream was derived by subtracting material generation estimates for the residential stream from estimates of the material generation rates for the combined IC&I and residential streams. The composition of the combined stream was based on data from a report by MM Dillon consultants which reported composition estimates for northern communities (the data were provided by the Northwest Territories). The C&D waste stream composition was taken from the SENES report on C&D waste in Canada (SENES, 1993).

Estimates of recycling and composting provided by in the Northwest Territories were adopted. Assumptions were made as follows to allocate materials recycled to the respective sources. The 100 tonnes recovered by the Ecology North Yellowknife program were assumed to be split 40% paper, 40%, glass 5% aluminum and 5% ferrous. These were further split equally among the residential and IC&I sectors. The residential portion was assumed to be old newspaper while the IC&I portion was assumed to be old corrugated cardboard. The 85.5 tonnes of fine paper was assumed to be recovered from the IC&I sector. It should be noted that glass recovered at depots is crushed and used for landfill cover rather than shipped for recycling (Wolnik, 1995). It was assumed that all auto hulks were diverted from municipal landfills. Beer cans and bottles recovered were not included in the analysis as these generally have not been considered part of the waste stream. Estimates of C&D waste recovery were taken from the SENES report on C&D waste (SENES, 1993).

There were no active incinerator facilities in the Northwest Territories in 1992.

For each material, the quantity landfilled was derived from the estimated waste generated less the estimated quantities recycled/composted.

3.7 Manitoba

The following summarizes the population and the estimated quantity and composition of solid waste generated, diverted, combusted and landfilled in Manitoba in 1992.

- Population of Manitoba was approximately 1,096,000.
- An estimated 1,299,000 tonnes of waste were generated consisting of:
  - 465,000 tonnes of residential waste,
  - 493,000 tonnes of IC&I waste, and
  - 342,000 tonnes of C&D waste.
- This represents a per-capita generation rate of 1.19 tonnes/cap./yr.
- An estimated 150,000 tonnes of waste was diverted consisting of:
  - 5,000 tonnes from residential sources,
  - 64,000 tonnes from IC&I sources, and
  - 81,000 tonnes of C&D material.
- An estimated 1,150,000 tonnes of waste were landfilled consisting of:
  - 460,000 tonnes from residential sources,
  - 429,000 tonnes from IC&I sources, and
  - 261,000 tonnes was C&D material.
- No waste was combusted.

Estimates have been based on waste disposal and recycling data provided to Environment Canada by Manitoba Environment for the NSWI. Also, additional data on residential, IC&I and C&D waste generation and on composting were incorporated from other sources (SENES, 1993; SENES, 1993a; Composting Council of Canada, 1993; B.C. Ministry of Environment, 1991; CH2M Hill, 1990).

An estimate of per-capita waste disposal of 0.811 t/cap/ yr, based on information in the State of the Environment Report (provided by Manitoba Environment), was used for estimating waste generation. This disposal rate was assumed not to include most C&D waste. Estimates of C&D waste generation were therefore taken from the SENES report on C&D waste in Canada (SENES, 1993).

A first estimate of waste generation of 888,856 tonnes from the residential and IC&I sectors was made by multiplying the disposal rate (0.811 t/cap/yr) by the provincial population (1,096,000). Estimates of waste recycled and composted also have been added. Estimates of beverage containers recycled were based on data from Manitoba Environment (RIS files), totalling 3,514 tonnes (the estimate ignored refillable glass and aluminum beverage containers which were assumed not to be part of the waste stream). Estimates of organic waste composted were based on data on centralized composting facilities (874 tonnes of leaf and yard waste) and on backyard composters distributed in Winnipeg (537 tonnes of food and yard waste); they were taken from a 1993 survey by the Composting Council of Canada and a follow-up survey performed by SENES (Composting Council of Canada, 1993; SENES, 1993a). No data were available on possible recovery of other materials (e.g., paper products) in the IC&I and residential streams, so they were assumed to be zero for this analysis. (This may yield a low estimate for recovery in Manitoba.)

Therefore, the total waste estimated to be recycled in the residential and IC&I sectors is 4,925 tonnes (not including auto hulks). An estimate for the generation of auto hulks was added based on a generation rate estimated from Ontario (63,568 tonnes) (CH2M Hill, 1990). Estimates of C&D waste generation (342,094 tonnes) were taken from the SENES report on C&D waste in Canada (SENES, 1993). Therefore the overall waste generated was estimated to be 1,229,439 tonnes.

The total waste generated from the residential and IC&I sectors, not including auto hulks (893,781 tonnes), was allocated to each of these sectors according to data from a sampling study conducted in Saskatoon, Saskatchewan which indicated the relative quantities from these sources: residential accounting for 52% of waste, IC&I accounting for 48% of the waste. The report actually indicates the distribution for the entire waste stream (including C&D): 39% residential, 36% IC&I, 25% C&D. Therefore the overall waste generated was assumed to consist of 464,764 tonnes of residential waste, 492,581 tonnes of IC&I waste and 342,094 tonnes of C&D waste (as estimated by SENES, 1993).

The composition of the generated waste streams was determined from other sources. The IC&I waste stream composition estimation was based on a study of three communities in B.C. (B.C. Ministry of Environment, 1991). The IC&I waste stream in Kamloops, B.C. was used, because it represents an estimate for a small interior city and was therefore considered to be representative of the IC&I sector in the province of Manitoba.

The residential waste stream composition was then derived by subtracting estimates for the IC&I waste stream from estimates of the overall waste stream composition based on data for the Manitoba waste stream reported in 1990 by the Manitoba Recycling Action Committee, (MRAC) (MRAC, 1990). The composition was assumed not to include white goods so an estimate was made based on estimated white goods generation in Ontario (2.5% of the residential waste stream) (CH2M Hill, 1991). The composition of the C&D waste stream was taken from the SENES report (SENES, 1993).

The composition of the recycled stream was based on the Manitoba Department of Environment data on beverage containers [RIS files]. All auto wrecks were assumed to be diverted from municipal landfills (63,568 tonnes). C&D waste diversion (81,418 tonnes) was taken from the SENES report on C&D waste in Canada (SENES, 1993). Therefore the total waste diverted was estimated to be 149,911 tonnes.

According to the data available, there were no active incinerators in Manitoba in 1992.

Waste disposed in landfills for each waste stream was then estimated by subtracting the estimates of waste diverted from the estimated waste generated.

3.8 Ontario

The following summarizes the population and the estimated quantity and composition of solid waste generated, diverted, combusted and landfilled in Ontario in 1992.

- Population of Ontario was approximately 9,625,000.
- An estimated 13,519,000 tonnes of waste were generated consisting of:
  - 4,332,000 tonnes of residential waste,
  - 4,031,000 tonnes of IC&I waste, and
  - 5,156,000 tonnes of C&D (DLC) waste.
- This represents a per-capita generation rate of 1.40 tonnes/cap/yr.
- An estimated 6,338,000 tonnes of waste was diverted consisting of:
  - 705,000 tonnes from residential sources,
  - 1,463,000 tonnes from IC&I sources, and
  - 4,170,000 tonnes of C&D material.
- An estimated 277,000 tonnes of waste were sent for combustion, all to EFW facilities.
- An estimated 83,000 tonnes of ash/residue were generated during combustion.
- An estimated 6,987,000 tonnes of waste were landfilled consisting of:
  - 3,481,000 tonnes from residential sources,
  - 2,520,000 tonnes from IC&I sources, and
  - 987,000 tonnes was C&D material.

Estimates have been based on waste generation, disposal (combustion and landfilling) and recycling data provided in a memo from the Ministry of Environment and Energy (MOEE) to Environment Canada (Breeze, 1994) for the NSWI. Also, additional data on C&D waste generation, on composting and on recycling were incorporated from other sources (SENES, 1993; SENES, 1993a; Composting Council of Canada, 1993; Ministry of Environment and Energy [MOEE], 1994; CH2M Hill, 1990; Ontario Ministry of Environment, 1991; Environment Canada, 1994).

Residential waste generation was first estimated by adding the total waste disposed of (provided by MOEE—3,627,000 tonnes) to estimates of recycling and composting. An estimate of diversion through the Blue Box program in Ontario provided by MOEE (431,480 tonnes) was used. Composting data were taken from the 1993 survey on composting by the Composting Council of Canada and followup work by SENES (SENES, 1993a). These sources estimated that 136,737 tonnes of residential yard waste were composted in central facilities. An estimated 28,913 tonnes of yard waste and 61,440 tonnes of food waste were composted in 668,692 backyard composters; based on a diversion rate of 169 kg per composter and 80% effective use (Composting Council of Canada, 1993; SENES, 1993a; MOEE, 1994).

The estimate of waste disposed was assumed not to include some white goods diverted. An estimate of white goods generation (109,000 tonnes) was based on a report on steel shredding in Ontario (CH2M Hill, 1990). It was assumed that a portion of the white goods was landfilled and is accounted for in the disposed of waste figures provided by MOEE (Breeze, 1994). An estimate of 50% diversion of white goods was assumed.

Waste composition studies have been conducted in several Ontario communities. These include Centre and South Hastings, East York, Fergus, Mississauga, Guelph, Kingston, Ottawa and North Bay. Additional studies are currently under way. The composition of the generated residential waste stream was taken from waste composition data in several of these Ontario studies and summarized in the 1994 report on the GTA 3Rs Analysis, (MOEE, 1994). The composition used for the GTA 3Rs Analysis combining data from the other studies, was also adopted for this analysis (MOEE, 1994). The estimate for white goods was added, assuming it represented 2.5% of the waste stream (CH2M Hill, 1990).

An estimate of the IC&I waste generation in Ontario was also derived by summing data on the waste disposed of (provided by the Waste Reduction Office [WRO]) with estimates of recycling and composting. In the absence of reliable, detailed information on recycling in the IC&I sector in Ontario, an estimate of the overall recycling rate for the IC&I stream (based on recycling rates for each material) from the report of the GTA 3Rs analysis was incorporated in the IC&I waste generation estimate, which was derived from data provided by the WRO.

Composting data for the IC&I stream (12,920 tonnes of IC&I waste composted in central composting facilities—this estimate is considered low) were taken from the report by the Composting Council of Canada (Composting Council of Canada, 1993).

The estimate of waste disposed of, provided by the WRO, did not include auto hulks. Estimates of auto hulks (558,000 tonnes—based on an estimate of 0.058 tonnes per capita per year) were based on a report on steel shredding in Ontario (CH2M Hill, 1990).

Therefore, it is estimated that a total of 4,026,052 tonnes of IC&I waste were generated and 1,461,900 tonnes of IC&I waste were diverted.

Additional data on C&D waste generation were taken from the SENES, 1993 report. For this preliminary analysis, it has been assumed that asphalt and concrete from road and bridge construction are not included in the estimate of waste disposed of in 1992 provided by the WRO (Breeze, 1994). Therefore the data on this in the SENES report are added (totalling 3,464,000 tonnes). It was been assumed that C&D waste disposed of is included in the IC&I waste disposed of reported by WRO (3,554,000 tonnes). However, if data on the quantities of disposed of C&D waste from the SENES report (1,609,967 tonnes) are applied to the IC&I data reported by WRO (3,554,000 tonnes), an unrealistically low value for IC&I waste results (1,944,033 tonnes). One possible reason for this is that the estimate of diversion of building-related C&D waste in the SENES report is very low (e.g., using one facility's recovery of gypsum for the provincial figure); assuming that no building materials other than wood are diverted might also affect the data.

Therefore the diversion rates of C&D materials, for this analysis, have been based on the diversion rates estimated in a 1994 waste management study for the greater Toronto area (MOEE, 1994). The diversion rates from that study have been applied to estimates of C&D waste generation in Ontario from the 1993 report by SENES. The resulting estimate of C&D waste disposed of (986,530 tonnes) was subtracted from the figure for IC&I waste disposed of reported by the WRO (3,554,000 tonnes) (MOEE, 1994). This yielded an estimate of IC&I waste disposed of (landfilled and combusted) of 2,567,470 tonnes, which is considered more reasonable.

The composition of the generated IC&I waste stream was also assumed from the GTA 3Rs Analysis report, recognizing that the makeup of IC&I waste stream depends on the local economy. The quantities of each material recycled from the IC&I stream were then estimated based on the rates taken from the GTA 3Rs Analysis report.

The quantities combusted were not reported explicitly by MOEE (Breeze, 1994). Estimates of waste combusted were therefore taken from summaries of active incinerators in Canada (Environment Canada, 1994 and 1994b). It was assumed that quantities of wastes disposed of at incinerator facilities were included in the estimates of waste disposed of provided by MOEE (3,554,000 tonnes). Data on actual throughputs in 1993 for the five active incinerators in Ontario (General Motors Canada, Hamilton-Wentworth Solid Waste Reduction Unit, Peel Resource Recovery Inc., 3M Canada and Victoria Hospital) were used (totalling 276,900 tonnes). Ash/residue generation rates reported were, on average, very close to the assumption of 30% generally applied in this analysis; thus 30% ash/residue generation was used in this case also. For the facilities reported to process MSW, it was assumed that 80% of the feed was generated by residential sources while 20% was generated by IC&I sources. All of the waste processed at the General Motors facility was assumed to be generated in-house and therefore is part of the IC&I stream. The composition of the total feed to all incinerators was assumed to be the composition of the overall waste disposed of from each of the residential and IC&I waste streams (waste generated less waste diverted).

The quantities of each material landfilled were derived by subtracting the estimates of combusted and recycled waste from the estimated waste generated. The estimate of ash/residue generated during combustion was added to the landfilled stream figure.

3.9 Quebec

The following summarizes the population and the estimated quantity and composition of solid waste generated, diverted, combusted and landfilled in Quebec in 1992.

- Population of Quebec was approximately 6,926,000.
- An estimated 8,028,000 tonnes of waste were generated consisting of:
  - 2,592,000 tonnes of residential waste,
  - 3,836,000 tonnes of IC&I waste, and
  - 1,600,000 tonnes of C&D (Demolition Land Clearing) waste.
- This represents a per-capita generation rate of 1.16 tonnes/cap/yr.
- An estimated 1,773,000 tonnes of waste was diverted consisting of:
  - 250,000 tonnes from residential sources,
  - 1,350,000 tonnes from IC&I sources, and
  - 173,000 tonnes of C&D material.
- An estimated 541,000 tonnes of waste were sent for combustion:
  - 517,000 tonnes to EFW facilities,
  - 24,000 tonnes to facilities without energy recovery.
- An estimated 162,000 tonnes of ash/residue were generated during combustion.
- An estimated 5,876,000 tonnes of waste were landfilled consisting of:
  - 2,039,000 tonnes from residential sources,
  - 2,410,000 tonnes from IC&I sources, and
  - 1,427,000 tonnes was C&D material.

Estimates have been based on waste generation, disposal and recycling data provided in a memo from the Quebec Ministry of the Environment to Environment Canada (Durocher, 1993) for the NSWI. Also, additional data on C&D waste, on composting and on recycling were incorporated from other sources (SENES, 1993; SENES, 1993a; Composting Council of Canada, 1993; MOEE, 1994; CH2M Hill, 1990; Ontario Ministry of Environment, 1991; CEDEGER, 1993; Gouvernement du Québec, Urgel Delisle, 1994; Department of Environment and Wildlife, 1995).

Overall waste generation was first estimated by adding the total waste generated of (7,223,000 tonnes) reported by the province (this includes recycling, combustion, some composting and some C&D waste) to estimates of waste assumed not to be included in this total. It has been assumed that C&D waste generated from road- and bridge- building activities was not included in the IC&I waste disposal and recycling data provided by the province. The Department of Environment and Wildlife provided information, based on an unpublished report by Serrener Consultants, that C&D waste disposal was estimated to be 1.5 million tonnes in 1992 (Jalbert, 1995). Since a detailed breakdown of this estimate was not available at the time of preparing this report, data from the SENES report on C&D waste (SENES, 1993) were used for building-related waste (907,600 tonnes). The difference between 1.6 million tonnes reported by Serrener and this figure was assumed to be road- and bridge-related waste disposed of. A diversion rate of 25% of this figure (173,000 tonnes) has been assumed as in the SENES report.

Also, estimates for composting were taken from Composting Council of Canada and SENES surveys. Over 20,500 tonnes of organics were assumed to have been composted in central facilities (Compost Council of Canada, 1993; SENES, 1993a). 1,480 tonnes of food and yard waste were assumed to have been composted in 10,948 backyard composters reported distributed, based on a diversion rate of 169 kg per composter and 80% effective use (SENES, 1993a; MOEE, 1994). This figure was used in place of the data from the province (17,000 tonnes) as it was considered more comprehensive.

Therefore the overall waste generated was estimated, by summing the above estimates, to be 8,612,694 tonnes.

Estimates were also made for auto wrecks (180,000 tonnes), based on information provided by the Department of Environment and Wildlife (Jalbert, 1995) and for white goods (64,800 tonnes-2.5% of the residential waste stream in Ontario (CH2M Hill, 1990). However, these were assumed to be included in the figure for metal recycled and were not added to the waste-generation figure because the recycling rate reported by the estimates for metals appears very high (1,012,000 tonnes). This is possibly attributed to a significant amount of metal from IC&I sources that is not generally reported in the municipal waste stream composition and generation studies. Therefore, the analysis first assumed a typical metal composition for the IC&I waste stream generated based on metal waste generation, recycling and disposal data reported for residential and IC&I waste streams in Ontario and Quebec (MOEE, 1994; CEDEGER, 1993; Durocher, 1994). Then an estimate was made of how much metal in excess of expected levels was included in the provincial figures, based on the Ontario and Quebec data above. This excess was then re-incorporated into the expected IC&I total in order to maintain the provincial total. In estimating the amount of metal expected to have been recycled, data from the report on the greater Toronto area (GTA) waste stream (MOEE, 1994) were used. These data were modified to account for the higher use of aluminum beverage containers in Quebec in 1992. The excess was estimated to be approximately 913,533 tonnes of metal, of which, for the purposes of this analysis, a portion (244,806 tonnes) was attributed to the estimate of auto wrecks and white goods generation. The balance (668,727 tonnes) was added to the metal generation, split between ferrous and commingled metal according to the modified data for Ontario.

The overall waste generated was allocated to the residential, IC&I and C&D sectors according to data provided by the province: 33% residential, 39% IC&I and 18% C&D. The C&D waste generated was estimated to be 1,600,000 tonnes (Jalbert, 1995). The quantities of waste generated from residential and IC&I sources were then derived by subtracting this estimate from the estimated total generation (7,699,161 tonnes, not including the extra metal—913,533 tonnes) and allocating the balance according to the 33 to 39% ratio reported by the province: 2,527,446 and 2,986,981 tonnes respectively. Approximately 64,800 tonnes of white goods were added to the residential total; the balance of the extra metal, (848,727 tonnes, of which 180,000 tonnes has been assumed to be auto hulks) was added to the IC&I total.

The composition of the residential waste stream generated was taken from a 1989 waste composition study conducted in Quebec and reported in a feasibility study on managing the residential waste stream in Quebec (Urgel Delisle, 1994). The relative composition of materials within major material categories was further defined according to the estimated composition of the GTA waste stream (MOEE, 1944).

The composition of the IC&I waste stream generated was assumed to be similar to that of the estimated GTA waste stream (MOEE, 1994).

The composition of the residential recycling stream was assumed to be similar to that estimated for the GTA (MOEE, 1994). The total quantity of recycled residential materials reported by the province (163,000 tonnes, not including white goods) was broken out by material according to the GTA estimates (modified to consider the greater use of aluminum in beverage containers in 1992).

Waste recycled from IC&I sources was derived by subtracting the estimated quantity of each material recycled from residential sources from the overall recycling data provided by the province (Durocher, 1993).

Organic waste composted was estimated based on data from the Composting Council of Canada and additional estimates on backyard composting from SENES. For backyard composting, the split between food and yard waste composted (68% food and 32% yard waste) was based on studies of composter use in Ontario (Compost Management, 1990, 1993; Proctor & Redfern, 1994).

According to documentation provided by Environment Canada, there were three active incinerators in Quebec in 1992. The quantities incinerated were reported by the province to be 379,000 tonnes, not including ash/residue (Durocher, 1993). Data provided by Environment Canada were used to allocate the amount of materials handled by each facility (Environment Canada, 1994 and 1994b). It was assumed that the relative proportions processed by the Quebec Urban Community EFW facility, the Montréal Des Carrières EFW facility and the Levis non-EFW facility were similar to those reported in a document provided by Environment Canada (Environment Canada, 1994b): approximately 95.6% through the EFW facilities (based on reported 1992 throughput) and approximately 4.4% through non-EFW facilities (based on reported 1992 throughput). The general assumptions regarding combustion were applied: 30% of the incinerator feed was landfilled as ash/residue, 80% of the feed was generated from residential sources while 20% was generated from IC&I sources, and the composition of the incinerator feed was the composition of the overall waste disposed of (waste generated less waste diverted). Refer to section 2 of appendix A for additional details on the assumptions used for estimating the quantities and composition of waste combusted.

The quantities of each material landfilled were estimated by subtracting the estimate of waste sent for combustion and recycled or composted from the estimate of waste generated. The ash/residue generated by combustion is also reported in the waste landfilled column.

3.10 New Brunswick

The following summarizes the population and the estimated quantity and composition of solid waste generated, diverted, combusted and landfilled in New Brunswick in 1992.

- Population of New Brunswick was approximately 728,000.
- An estimated 598,000 tonnes of waste were generated consisting of:
  - 237,000 tonnes of residential waste,
  - 221,000 tonnes of IC&I waste, and
  - 140,000 tonnes of C&D waste.
- This represents a per-capita generation rate of 0.82 tonnes/cap/yr.
- An estimated 42,000 tonnes of waste was diverted consisting of:
  - 4,500 tonnes from residential sources,
  - 31,000 tonnes from IC&I sources, and
  - 7,000 tonnes of C&D material.
- An estimated 556,000 tonnes of waste were landfilled consisting of:
  - 233,000 tonnes from residential sources,
  - 190,000 tonnes from IC&I sources, and
  - 133,000 tonnes of C&D material.
- No waste was combusted.

Estimates have been based on waste generation, disposal and recycling data provided in a memo from the New Brunswick Department of the Environment (NBDOE) to Environment Canada (Glynn, 1994) for the NSWI. The data provided by New Brunswick were assumed by NBDOE to be for 1990. It was assumed that these data originated from a 1991 report on recycling in New Brunswick. (This was based on a series of waste audits performed around the province.) (New Brunswick Department of Environment, 1991). The data compare very closely with the data in that report and some of the waste audits reviewed (e.g., Fundy Region and Northumberland Region) (WMS, 1990 and 1990a), so the provincial data have been assumed to be the most reliable data available. Additional data have been incorporated from other sources (SENES, 1993l; SENES, 1993a; Composting Council of Canada, 1993; MOEE, 1994; Ontario Ministry of Environment, 1991; Newplan Consultants, 1993).

Overall waste generation was first estimated by adding the total waste disposed of in 1992 (provided by NBDOE—463,434 tonnes for the NSWI) to estimates of wastes assumed not to be included in this estimate (some C&D waste and waste recycled and composted). While the generation estimates provided indicate that C&D waste is included (C&D is indicated in the column heading with IC&I), it was assumed that the disposal rate of 463,434 tonnes did not include some C&D wastes such as road- and bridge-construction waste for the following reasons:

- The per-capita disposal rate was relatively low.
- The quantity of the "other" waste category in the 1990 composition analysis provided is relatively low.
- Composition data in the two waste audits noted above were based on the 1978 Bird & Hale study, which did not include much of the C&D waste.

Therefore, additional data on C&D waste generation, disposal and recycling taken from the SENES report on C&D waste in Canada were also incorporated. It has been assumed that asphalt, concrete and rubble (17,221, 10,512 and 71,728 tonnes respectively) were not included in the estimate of waste disposed of in 1992 or in the estimate of waste generated in 1990. Therefore, these are added to the 463,434 tonnes reported disposed of by NBDOE. However, it has been assumed that C&D materials, including metals, paper, building materials, gypsum and "other" materials (40,442 tonnes based on SENES report)—are included in the waste disposal estimates provided by NBDOE.

Estimates of waste recycled provided by the NBDOE and summarized by Environment Canada (totalling 7,850 tonnes) were also added to the estimate of waste generated.

Also, based on the published reports reviewed, it was assumed that the New Brunswick disposal and generation data (provided by NBDOE) included estimates for both white goods and tires disposed of, although the estimates are considered uncertain. An estimate for auto hulks generated (26,940 tonnes) was added to the provincial data, based on an estimate of 0.037 tonnes per-capita of auto hulks generated in St. John's, Newfoundland (Newplan Consultants, 1993).

SENES reported that 100 backyard composters had been distributed by 1992 in New Brunswick (SENES, 1993a). Assuming 80% effective use with a diversion rate of 169 kg/composter/yr, an estimate of 13.5 tonnes of waste was diverted through composting. This was assumed to be 68% food and 32% leaf and yard waste (Compost Management Ass., 1990, 1993; Rivers, 1994). The city of Fredericton reported 630 tonnes of yard waste composted in 1992 (RIS files). These figures were also added to the estimate of waste generated.

The total waste generated—598,329 tonnes, estimated by summing the above data—was then allocated to the IC&I and residential sectors according to the relative proportion of IC&I and residential waste reported generated in 1990 (NBDOE, 1994). This estimate was assumed not to include auto hulks, or the C&D waste assumed to be included in the waste generation estimate (40,442 tonnes). According to data provided by the province, residential sources accounted for 55% of the combined residential and IC&I waste generated (not including auto hulks), while IC&I sources accounted for 45%.

Therefore, after subtracting the auto hulks (estimated to be 26,940 tonnes) and subtracting the C&D waste assumed to be included in the province's waste generation estimate (40,442 tonnes) from the overall waste generation estimate (598,329 tonnes), the residential and the IC&I waste generation were estimated to have been 231,291 tonnes and 194,194 tonnes respectively. Auto hulks were then added to the IC&I stream.

The composition of the waste-generated streams was assumed to be the same as that reported for 1990 by NBDOE. The estimate of organic waste generated was separated into food and leaf and yard waste according to data from a 1991 report by the New Brunswick Department of Environment (New Brunswick Department of Environment, 1991). That report estimated yard waste to be 5% of the waste stream.

Recycling rates provided by NBDOE were allocated to the residential and IC&I sectors as follows: all old newspaper (ONP) (1,338 tonnes) to the residential sector; all office paper (1,435 tonnes) to the IC&I sector; plastic, glass and metal materials (5,002 tonnes) and telephone directories (75 tonnes) were split equally between residential and IC&I sectors.

There are no active incinerators in New Brunswick.

The waste landfilled was then estimated by subtracting the waste recycled or composted from that generated.

3.11 Prince Edward Island

The following summarizes the population and the estimated quantity and composition of solid waste generated, diverted, combusted and landfilled in Prince Edward Island (PEI) in 1992.

- Population of PEI was approximately 130,000.
- An estimated 110,000 tonnes of waste were generated consisting of:
  - 35,000 tonnes of residential waste,
  - 68,000 tonnes of IC&I waste, and
  - 6,000 tonnes of C&D (DLC) waste.
- This represents a per-capita generation rate of 0.84 tonnes/cap/yr.
- An estimated 14,000 tonnes of waste was diverted consisting of:
  - 2,000 tonnes from residential sources,
  - 11,000 tonnes from IC&I sources, and
  - 200 tonnes of C&D material.
- An estimated 30,000 tonnes of waste were sent for combustion to EFW facilities.
- An estimated 9,000 tonnes of ash/residue were generated during combustion.
- An estimated 75,000 tonnes of waste were landfilled consisting of:
  - 16,000 tonnes from residential sources,
  - 53,000 tonnes from IC&I sources, and
  - 6,000 tonnes of C&D material.

Estimates have been based on waste disposal and recycling data provided in a memo from Prince Edward Island Department of Environmental Services (PEI DES) to Environment Canada (Stewart, 1994) for the NSWI. However, additional data on C&D waste taken from the SENES report on C&D waste in Canada (SENES, 1993) and data on composting taken from the 1993 survey by the Composting Council of Canada (Composting Council of Canada, 1993) were also incorporated. Since there was limited composition data from PEI, the estimated composition of the Nova Scotia waste streams, based on the Nova Scotia waste audits, were used to derive the composition of the PEI waste stream (Vaughan Engineering Ass., 1994; Neill and Gunter (NS), 1994; Newplan Consultants, 1993). (Refer to section 3.12 of appendix A)

Estimates of waste generation were developed by summing reported estimates of the waste disposed of (residential: 33,000 tonnes; IC&I: 57,000 tonnes) and the waste recycled (residential: 1,075 tonnes, IC&I: 5,930 tonnes recycled) and estimates of waste composted (Stewart, 1993). It was assumed that the province's estimate of C&D waste disposed of (5,000 tonnes) did not include road and bridge construction waste (Stewart, 1994). Data for this were therefore taken from the SENES report on C&D waste (714 tonnes disposed of and 238 tonnes recycled) (SENES, 1993). Also, an estimate of the organic waste composted (336 tonnes of leaf and yard waste), was not included in recycling and disposal estimates provided by the province and therefore was taken from a 1993 survey on composting facilities (Composting Council of Canada, 1993).

Estimates of the composition of the residential, IC&I and C&D generated waste streams in Nova Scotia were applied to the overall generation rates estimated for PEI. However, to account for the different legislation affecting beverage containers in PEI, estimates of the aluminum and polyethylene/terephthalate (PET) were redistributed to "other metals" and "plastics" respectively. The quantities of tires (739 tonnes) and white goods (820 tonnes) reported by the province were assumed to be diverted (and not included in amounts reported disposed of). An estimate for auto hulks generated (4,821 tonnes) was added, based on an estimate of 0.037 tonnes per-capita of auto hulks generation in St. John's, Newfoundland (Newplan Consultants, 1993). These were all added to estimates of the waste disposed of; (this is different from the assumption behind the disposed of waste data in table 1 NSWI provided by Environment Canada in which white goods, contaminated soil and tires may have been assumed to have been included in the provincial figures for waste disposed of).

Recycling rates provided by PEI DES were used, but assumptions were also made regarding the materials recycled in order to make further estimates of the disposed of waste stream composition. It was assumed that all residential paper recycled was ONP; 80% of IC&I paper recycled was old corrugated containers (OCC), while the remaining 20% of IC&I paper recycled was fine paper. All glass recycled was assumed to be container glass. Metal recycled was assumed to be all ferrous.

The quantity of waste combusted reported by the province (29,843 tonnes) has been assumed to represent the feed stream to the incinerator (i.e., ash included). The quantity of ash/residue was reported as 8,950 tonnes. It has been assumed that the waste feed to the incinerator was primarily residential waste (80%—23,874 tonnes including ash/residue), while the balance (20%—5,969 tonnes including ash/residue) was IC&I waste. The ash/residue was included with inorganic material landfilled.

For each material, the quantities of waste landfilled were calculated by subtracting the waste recycled/composted as well as the quantities sent for combustion from the estimated quantities generated. The estimated ash/residue generated during combustion was added to the landfilled stream.

3.12 Nova Scotia

The following summarizes the population and the estimated quantity and composition of solid waste generated, diverted, combusted and landfilled in Nova Scotia in 1992.

- Population of Nova Scotia was approximately 903,000.
- An estimated 722,000 tonnes of waste were generated consisting of:
  - 346,000 tonnes of residential waste,
  - 316,000 tonnes of IC&I waste, and
  - 61,000 tonnes of C&D (DLC) waste.
- This represents a per-capita generation rate of 0.8 tonnes/cap/yr.
- An estimated 74,000 tonnes of waste was diverted consisting of:
  - 16,000 tonnes from residential sources,
  - 49,000 tonnes from IC&I sources, and
  - 9,000 tonnes of C&D material.
- An estimated 57,000 tonnes of waste were sent for combustion 28,000 tonnes to EFW facilities and 29,000 tonnes to facilities without energy recovery.
- An estimated 17,000 tonnes of ash/residue were generated during combustion.
- An estimated 608,000 tonnes of waste were landfilled consisting of:
  - 298,000 tonnes from residential sources,
  - 259,000 tonnes from IC&I sources, and
  - 51,000 tonnes of C&D material.

Data from four regional waste management studies—Northern Region (Vaughan Engineering, 1994a), South Shore/Valley Region (Vaughan Engineering, 1994b), Cape Breton Island (Vaughan Engineering, 1994), and the Annapolis Valley/Southwestern Region (Neill and Gunter, 1994)—as well as other data available are considered more comprehensive and up to date than the data provided by the province to Environment Canada for the NSWI. Therefore, these data have been used for this analysis. A note included with the data sent by the Nova Scotia Department of Environment to Environment Canada concerning waste generation and disposal estimates indicated that more accurate waste generation, recycling and disposal data would be available in these regional reports.

Disposal data from the Northern Region, the South Shore/Valley Region and Cape Breton Island were taken from the reports of the waste audit conducted for these regions. The Annapolis

Valley/Southwestern Region audit was done with a slightly different methodology and so, in order to be consistent, the data from the other three regional studies were used on the assumption that they are sufficiently representative of the Annapolis Valley Region (Vaughan Engineering Ass., 1994; Neill and Gunter [NS], 1994).

Little comprehensive data was available for Metro Halifax at the time of this analysis, although a waste audit has been conducted for Halifax and likely contains relevant information. Therefore, disposal data from Kings County (taken from the South Shore/Valley Region waste audit) were assumed to be sufficiently representative of Metro Halifax due to the large IC&I presence.

Population data were taken from the waste audit reports (Shelburne and King's County data were taken from the South Shore report—17,400 and 56,700 respectively). Metro Halifax data were taken from RIS files (330,900 based on the 1991 Statistics Canada).

Residential disposed of (landfilled and combusted) waste estimates were developed by summing the waste disposed of by material as reported in each of the waste audit reports (Northern, South Shore/Valley and Cape Breton Island regions—totalling 310,000 tonnes). Estimates for the Annapolis Valley/Southwestern Region were derived by taking the weighted average per-capita residential waste disposed of in the Northern/South Shore and Cape Breton Island Regions (0.343 tonnes/cap/yr) and scaling it to the Annapolis Valley population (73,259). Estimates for Metro Halifax were derived similarly using King's County per-capita residential waste disposal data (0.267 tonnes/cap/yr), scaled to the Metro Halifax population (330,900). King's County was used because it was considered to have some urban population and a significant IC&I sector most applicable for comparison.

Based on the waste audits reviewed, it was assumed that the Nova Scotia data on disposed of quantities included estimates for tires and white goods, but the composition estimates (percent of waste stream based on composition studies conducted in Ontario) did not include white goods. Therefore, the composition estimates were modified to include white goods. White goods were assumed to represent 2.5% of the residential waste stream (CH2M Hill, 1990; MOEE, 1994).

IC&I disposed of (landfilled and combusted) waste data were taken from the reports in the same way as the residential data. Estimates were made for the Annapolis Valley and Metro Halifax IC&I streams based on data from the other regions, as was done for the residential waste stream. Disposal rates for the IC&I stream were estimated for Metro Halifax and the Annapolis Valley at 0.28 and 0.391 tonnes/cap/yr respectively.

The IC&I waste disposal data were assumed to include some C&D waste landfilled. However, the C&D waste data were separated from the IC&I waste stream for the purpose of this report. Data for the construction sector (generation rates and employment) as reported in the regional waste audits were used to determine the landfill rates for C&D wastes. Accordingly, based on employment in the construction sector relative to the entire IC&I sector, C&D waste was assumed to be 7.8% of total IC&I waste disposed of. This estimate is likely to be low, since it is based on the assumption that unit waste-generation rates are similar across all IC&I sectors, but it is considered sufficient for this analysis.

The composition of the construction sector waste stream reported in the waste audits was adopted for the C&D waste stream. This composition was taken primarily from the Metro Toronto SWEAP report (Proctor and Redfern, 1991). Estimates of C&D waste landfilled were assumed not to include road and bridge construction wastes. Estimates for these (28,497 tonnes) were taken from the SENES, 1993 report and added to the estimates of construction waste derived from the IC&I waste reported disposed of (estimated to be 7.8% of the IC&I waste either reported or estimated for each of the regions).

To derive the IC&I disposed of (landfilled and combusted) waste composition (disposal of each material), the C&D material landfill rates were then subtracted from the IC&I material disposal rates reported.

Data on combustion were also taken from the regional waste audits, but the data were very limited. There were eight active incinerators in Nova Scotia in 1992: Graywood and Crisp Road in Annapolis County, the Cape Breton County facility in Sydney, West Green Harbour in Shelburne, two facilities in Lunenburg, the *Advocate* incinerator in Cumberland County and the Gegogan Road facility in St. Mary's. For facilities for which disposal rates were not explicitly documented, disposal rates were assumed based on the limited information in the reports. It was assumed that residential waste represented, on average, 80% of waste incinerated, while IC&I (excluding C&D) waste represented the remaining 20%. A total of 56,705 tonnes (including ash/residue) was assumed to have been sent for combustion. Approximately 30% of the waste estimated to be combusted was assumed to require landfilling as ash/residue. This is included with inorganic material landfilled.

The composition of the incinerator feed was assumed to be essentially that of the waste disposed of (generated less diverted, and not including ash/residue generated during combustion and not including white goods). For the landfilled stream, the quantities of materials sent for combustion were subtracted from the total quantity of each material sent for disposal at landfills or incinerators (refer to the general notes on waste incineration in section 2 of appendix A), for details on the approach to these estimates and ash/residue was added to the landfilled stream.

Detailed data on waste recycled are very limited in the regional waste audit reports. Therefore, the data reported by the province on recycling (24,490 tonnes of commingled waste—taken from the National Solid Waste Tracking System summary provided by Environment Canada) were supplemented with data from the 1992 Clean Nova Scotia Foundation (CNSF) report on recycling to obtain a composition (Clean Nova Scotia Foundation, 1992). The CNSF reported overall recycling rates by material but not the source of recycled materials. Therefore assumptions as to the source of the waste were made as follows: all ONP was assumed to be from the residential sector, all OCC and fine paper were assumed to be from the IC&I sector; and other materials were split equally between the two. Estimates of recycling of asphalt and concrete C&D waste were taken from the SENES report on C&D waste in Canada (SENES, 1993).

Estimates of organic waste composted were taken from the 1992 Composting Council of Canada survey on centralized composting facilities and a follow-up survey by SENES (Composting Council of Canada, 1993; SENES, 1993a).

An estimate for auto hulks generated (33,413 tonnes) was incorporated, based on an estimate of 0.037 tonnes per capita for auto hulk generation in St. John's, Newfoundland (Newplan Consultants, 1993). It was assumed that all auto hulks were diverted.

Estimates of waste generation were then made by summing the estimates of waste landfilled, waste sent for combustion and waste diverted. (Note: The materials which were landfilled as part of ash/residue were not included in the inorganic category of waste generated, because they were included in the respective material categories of waste sent for combustion.)

3.13 Newfoundland

The following summarizes the population and the estimated quantity and composition of solid waste generated, diverted, combusted and landfilled in Newfoundland in 1992.

- Population of Newfoundland was approximately 576,000.
- An estimated 498,000 tonnes of waste were generated consisting of:
  - 167,000 tonnes of residential waste,
  - 301,000 tonnes of IC&I waste, and
  - 30,000 tonnes of C&D (DLC) waste.
- This represents a per-capita generation rate of 0.86 tonnes/cap/yr.
- An estimated 33,000 tonnes of waste was diverted consisting of:
  - 4,000 tonnes from residential sources,
  - 26,000 tonnes from IC&I sources, and
  - 4,000 tonnes of C&D material.
- An estimated 36,000 tonnes of waste were sent for combustion to facilities without energy recovery.
- An estimated 11,000 tonnes of ash/residue were generated during combustion.
- An estimated 439,000 tonnes of waste were landfilled consisting of:
  - 143,000 tonnes from residential sources,
  - 270,000 tonnes from IC&I sources, and
  - 26,000 tonnes of C&D material.

Detailed published data on waste management in Newfoundland is very limited, so the disposal data supplied by the province to Environment Canada for the NSWI were used as the basis of the waste quantities estimates. These data were taken from summary tables from the NSWI provided by Environment Canada. The estimates were supplemented with data from other sources (SENES, 1993a; Composting Council of Canada, 1993; Newplan Consultants, 1993; Environment Canada, 1994; see also section 3.12 of appendix A for sources of data for Nova Scotia that were also used for Newfoundland).

Overall waste generation was determined for each waste stream (residential, IC&I and C&D). The waste reported disposed of by the province (453,303 tonnes overall) was added to estimates from other sources of recycling and composting (totalling 7,560 tonnes and 894 tonnes respectively).

An estimate of C&D waste disposal provided by the province (14,675 tonnes) was assumed not to include road- and bridge-related C&D waste, since it was based only on disposal records for Robin Hood Bay landfill. Therefore, data from the SENES report on C&D waste in Canada (10,903 tonnes disposed of and 3,633 tonnes recycled) were used to supplement the province's estimate of waste disposed of.

It was assumed that the disposal and generation data provided by the province included estimates for both white goods and tires disposed of, although there is significant uncertainty in this assumption. An estimate for auto hulks generated (21,297 tonnes) was incorporated, based on an estimate of 0.037 tonnes per capita for auto hulks generation in St. John's, Newfoundland. (Newplan Consultants, 1993).

Therefore, total waste generated was estimated to be 497,591 tonnes by summing the aforementioned estimates.

The total waste disposed of (landfilled and combusted) was allocated to the residential, IC&I and C&D sectors according to the disposed of waste data provided by the province (residential: 163,308 tonnes; IC&I: 275,320 tonnes; C&D: 14,675 tonnes), and by making assumptions regarding the waste recycled and composted.

An estimate of the composition of the combined generated waste stream for the St. John's Urban

Region did not indicate separately the composition of the residential and IC&I waste streams. However, as indicated in the report, the overall composition compared favourably to data from New Brunswick (Newplan Consultants, 1993). Therefore, estimates of the composition of the residential and IC&I waste streams generated in New Brunswick (NBDOE, 1994) were applied to the Newfoundland overall waste generation rates (refer to section 3.10 of appendix A). For the C&D waste stream, Nova Scotia estimates were applied (they are more detailed and considered more reliable).

Data on recycling in Newfoundland is very limited. Estimates of recycling in the province were taken from the summary table of the NSWI provided by Environment Canada (totalling 7,560 tonnes). Data for 1992 recycling in the waste audit report for St. John's Urban Region do not provide any greater detail. The recycling rates from the NSWI summary table were allocated equally to each sector, except in the case of "commingled inorganic", which was attributed to the C&D sector. Also, the 800 tonnes of organic waste was attributed to the residential sector while the 94 tonnes of wood composted was attributed to the IC&I sector.

The quantity of municipal waste composted was taken from the NSWI summary table provided by Environment Canada, because it was greater than the estimate reported in the 1993 Composting Council of Canada survey and follow-up survey by SENES (SENES, 1993a) and considered more comprehensive.

Data on the quantity of waste combusted in Newfoundland is very limited. Estimates of quantities disposed of (totalling 25,916 tonnes assumed to include ash/residue) at two active incinerator facilities in the St. John's Urban Region (Holyrood and Conception Bay South) were taken from the St. John's waste audit report (Newplan Consultants, 1993). Also, estimates of waste disposed of at two other incinerators in Newfoundland (Harbour Grace and Labrador City) were taken from a 1994 survey of MSW incinerators in Canada (Environment Canada, 1994). For the latter two incinerators, actual throughput was assumed to be 80% of rated throughput (6,400 tonnes and 3,200 tonnes/yr respectively). The feed streams to all four facilities were assumed to be 80% residential and 20% IC&I waste. The feed composition was derived from the estimated waste generated less recycling/ composting for each material. Also, it was assumed that 30% of the feed stream would be landfilled as ash/residue. The quantity of ash/ residue is included with inorganic material landfilled.

For each material, the quantity landfilled was derived from the estimated waste generated less the estimated quantities recycled/composted less the quantities sent for combustion (refer to the general notes on waste incineration for details on the approach to these estimates in section 2.0 of appendix A), and ash/residue was added to the landfilled stream.

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Appendix B

Background to Cost Estimates

Table B-1 Estimated capital costs of landfills

Province	# of Landfills (1)	Total Capacity (tonnes)(2) individual landfills falling into the range of				Total
		0-500,000	500,001-4,000,000	4,000,001-7,000,000	7,000,001 +	
Newfoundland	2			6,000,000	16,000,000	22,000,000
PEI	3	815,000				815,000
Nova Scotia	7	1,533,227	4,900,000			6,433,227
New Brunswick	3	285,000	4,153,000			4,438,000
Quebec	13	810,400	11,577,300		45,000,000	57,387,700
Ontario	32	64,000	26,472,881	30,132,401	69,359,581	126,028,863
Manitoba	13	965,800	3,530,000		9,000,000	13,495,800
Saskatchewan	6	75,000	7,000,000		9,000,000	16,075,000
Alberta	16	534,280	8,048,653	6,000,000	14,000,000	28,582,933
British Columbia	15	685,236	10,675,507	4,000,000	37,000,000	52,360,743
NWT		405,000				405,000
Yukon	2	230,000				230,000
Total Capacity	**112**	**6,402,943**	**76,357,341**	**40,132,401**	**183,359,581**	**306,252,266**
Total Capital Costs (3)						
Low Estimates $/tonne		$19.10	$4.18	$3.04	$1.89	$7.05
Low Estimate Capital Costs		**$122,296,211**	**$319,173,685**	**$122,002,499**	**$346,549,608**	**$910,022,004**
High Estimates $/tonne		$22.42	$7.20	$5.10	$7.89	$8.46
High Estimate Capital Costs		**$143,553,982**	**$549,772,855**	**$204,675,245**	**$1,446,707,094**	**$2,344,709,176**
Gas Recovery Systems (4)						$68,746,094
Total Low Estimate Capital Costs						**$978,768,098**
Total High Estimate Capital Costs						**$2,413,455,270**

(1) as reported by Hickling (1994)
(2) based on information provided by Hickling (1994) each landfill that falls into one of the four capacity ranges summed in the appropriate cell ranges have been developed to reflect changes in capital and operating costs for different sizes of landfills
(3) based on information from MOEE (1991), VHB & Maclaren (1991), and GVRD (1993D); based on amortization rates for 20 years at 10%
(4) estimated costs based on information provided by Hickling (1994)

Table B-2 Estimated annualized capital costs of landfills

Province	# of Landfills (1)	Total Capacity (tonnes)(2) individual landfills falling into the range of				Total
		0-500,000	500,001-4,000,000	4,000,001-7,000,000	7,000,001 +	
Newfoundland	2			6,000,000	16,000,000	22,000,000
PEI	3	815,000				815,000
Nova Scotia	7	1,533,227	4,900,000			6,433,227
New Brunswick	3	285,000	4,153,000			4,438,000
Quebec	13	810,400	11,577,300		45,000,000	57,387,700
Ontario	32	64,000	26,472,881	30,132,401	69,359,581	126,028,863
Manitoba	13	965,800	3,530,000		9,000,000	13,495,800
Saskatchewan	6	75,000	7,000,000		9,000,000	16,075,000
Alberta	16	534,280	8,048,653	6,000,000	14,000,000	28,582,933
British Columbia	15	685,236	10,675,507	4,000,000	37,000,000	52,360,743
NWT		405,000				405,000
Yukon	2	230,000				230,000
Total Capacity	**112**	**6,402,943**	**76,357,341**	**40,132,401**	**183,359,581**	**306,252,266**
unit capital cost/tonne (3)						
Low Estimates $/tonne		$2.24	$0.49	$0.37	$0.23	$0.83
Low Estimate Annualized Capital Costs		**$14,342,592**	**$37,415,097**	**$14,848,988**	**$42,172,704**	**$108,779,381**
High Estimates $/tonne		$2.63	$0.85	$0.60	$0.93	$0.92
High Estimate Annualized Capital Costs		**$16,839,740**	**$64,903,740**	**$24,079,441**	**$170,524,410**	**$276,347,331**
Gas Recovery Systems (4)						$8,074,890
Total Low Estimate Annualized Capital Costs						**$116,854,271**
Total High Estimate Annualized Capital Costs						**$284,422,221**

(1) as reported by Hickling (1994)
(2) based on information provided by Hickling (1994) each landfill that falls into one of the four capacity ranges summed in the appropriate cell ranges have been developed to reflect changes in capital and operating costs for different sizes of landfills
(3) based on information from MOEE (1991), VHB & Maclaren (1991), and GVRD (1993D); based on amortization rates for 20 years at 10%
(4) estimated costs based on information provided by Hickling (1994)

Table B-3 Estimated annualized perpetual care costs for landfills

Province	# of Landfills (1)	Total Capacity (tonnes)(2) individual landfills falling into the range of 0-500,000	500,001-4,000,000	4,000,001-7,000,000	7,000,001 +	Total
Newfoundland	2			6,000,000	16,000,000	22,000,000
PEI	3	815,000				815,000
Nova Scotia	7	1,533,227	4,900,000			6,433,227
New Brunswick	3	285,000	4,153,000			4,438,000
Quebec	13	810,400	11,577,300		45,000,000	57,387,700
Ontario	32	64,000	26,472,881	30,132,401	69,359,581	126,028,863
Manitoba	13	965,800	3,530,000		9,000,000	13,495,800
Saskatchewan	6	75,000	7,000,000		9,000,000	16,075,000
Alberta	16	534,280	8,048,653	6,000,000	14,000,000	28,582,933
British Columbia	15	685,236	10,675,507	4,000,000	37,000,000	52,360,743
NWT	1	405,000				405,000
Yukon	2	230,000				230,000
Total Capacity	**113**	**6,402,943**	**76,357,341**	**40,132,401**	**183,359,581**	**306,252,266**
unit operating cost/tonne (3)						
Low Perpetual Care $/tonne		$1.27	$0.61	$0.49	$0.36	$0.68
Low Estimate Annualized Perpetual Care		**$8,131,738**	**$46,577,978**	**$19,664,876**	**$66,009,449**	**$140,384,041**
High Perpetual Care $/tonne		$1.29	$0.66	$0.53	$0.54	$0.76
High Estimate Annualized Perpetual Care Costs		**$8,259,796**	**$50,395,845**	**$21,270,173**	**$99,014,174**	**$178,939,988**

(1) as reported by Hickling (1994)
(2) based on information provided by Hickling (1994) each landfill that falls into one of the four capacity ranges summed in the appropriate cell ranges have been developed to reflect changes in capital and operating costs for different sizes of landfills
(3) based on information from MOEE (1991), VHB & Maclaren (1991), and GVRD (1993D); based on amortization rates for 20 years at 10%

Table B-4 Estimated annual landfill operating and maintenance costs (no capital allowance)

Province	# of Landfills (1)	Total Capacity (tonnes)(2)				
		individual landfills falling into the range of				
		0-500,000	500,001-4,000,000	4,000,001-7,000,000	7,000,001 +	Total
Newfoundland	2			6,000,000	16,000,000	22,000,000
PEI	3	815,000				815,000
Nova Scotia	7	1,533,227	4,900,000			6,433,227
New Brunswick	3	285,000	4,153,000			4,438,000
Quebec	13	810,400	11,577,300		45,000,000	57,387,700
Ontario	32	64,000	26,472,881	30,132,401	69,359,581	126,028,863
Manitoba	13	965,800	3,530,000		9,000,000	13,495,800
Saskatchewan	6	75,000	7,000,000		9,000,000	16,075,000
Alberta	16	534,280	8,048,653	6,000,000	14,000,000	28,582,933
British Columbia	15	685,236	10,675,507	4,000,000	37,000,000	52,360,743
NWT	1	405,000				405,000
Yukon	2	230,000				230,000
Total Capacity	113	6,402,943	76,357,341	40,132,401	183,359,581	306,252,266
assume 20 year capacity		221,686	1,960,448	300,000	3,850,000	6,332,134
assume 25 year capacity		62,569	1,485,936	1,365,296	4,254,383	7,168,184
assume 50 year capacity				120,000	320,000	440,000
annual landfill		284,256	3,446,383	1,785,296	8,424,383	13,940,318
unit operating cost/tonne (7)						
Low Estimates $/tonne		$6.91	$1.85	$1.40	$0.95	$2.78
Low Estimate Operating Costs		$1,964,206	$6,375,809	$2,499,414	$8,003,164	$18,842,594
Medium Estimate $/tonne		$24.11	$14.23	$13.05	$6.73	$14.53
Medium Estimates Operating Costs		$6,851,982	$49,024,801	$23,298,113	$56,653,977	$135,828,873
High Estimates $/tonne		$41.30	$26.60	$24.70	$12.50	$26.28
HIgh Estimate Operating Costs		$11,739,758	$91,673,792	$44,096,812	$105,304,791	$252,815,153
Unreported Small Landfills(3)	24.11	3,580,727	@ $24/tonne (5)			$86,331,328
C&D waste(4)	15	4,541,946	@ $15/tonne (6)			$68,129,190
Total Low Estimate Operating Costs						**$173,303,112**
Total Medium Estimate Operating Costs						**$290,289,391**
Total High Estimate Operating Costs						**$407,275,671**

(1) as reported by Hickling (1994)
(2) based on information provided by Hickling (1994) each landfill that falls into one of the four capacity ranges summed in the appropriate cell ranges have been developed to reflect changes in capital and operating costs for different sizes of landfills
(3) An estimation has been made of the amount landfilled in small unreported landfills.
(4) An estimation has been made of the amount of C&D waste landfilled.
(5) Operating costs are based on the medium operating costs to operate a small landfill.
(6) An average of the operating costs for different sized landfills has been used.
(7) operating costs from GVRD (1993D), MOEE (1991), VHB and Maclaren (1991)

Table B-5 Estimated capital costs for incinerators/energy from waste facilities

Province	# of Incinerators Facilities (1)	Annual Capacity	# of EFW Facilities (1)	Annual Capacity	Known Capital Costs (2)	Remaining Annual Capacity	Total Annual Capacity
Newfoundland	4	35,516	0	0		0	35,516
PEI	0	0	1	29,843		29,843	29,843
Nova Scotia	6	28,975	1	27,730		0	56,705
New Brunswick	0	0	0	0		0	0
Quebec	1	24,085	2	517,344		517,344	541,429
Ontario	0	0	5	276,900	112,238,583	98,700	276,900
Manitoba	0	0	0	0		0	0
Saskatchewan	0	0	0	0		0	0
Alberta	0	0	0	0		0	0
British Columbia	4	22,500	1	235,000	81,200,000	0	257,500
NWT	0	0	0	0		0	0
Yukon	0	0	0	0		0	0
Total Capacity	**15**	**111,076**	**10**	**1,086,817**	**193,438,583**	**645,887**	**1,197,893**
Estimated Capital Costs per Tonne		(3)		(4)			
Low Estimate $/tonne		$218.00		$398.00			
Low Estimated Capital Costs		**$24,214,568**		**$257,063,026**	**$193,438,583**		**$450,501,609**
Medium Estimate $/tonne		$221.00		$460.00			
Medium Estimated Capital Costs		**$24,547,796**		**$297,108,020**	**$193,438,583**		**$490,546,603**
High Estimate $/tonne		$235.00		$507.00			
High Estimated Capital Costs		**$26,102,860**		**$327,464,709**	**$193,438,583**		**$520,903,292**

(1) based on information from Hickling (1994), Quebec, Vaughan et al. (1994) and Neill and Gunter (1994)
(2) based on information from RIS (1994) and MOEE (1992); EFW capital costs provided for Burnaby, B.C.; Peel, Ontario; SWARU, Ontario; and Victoria Hospital, Ontario
(3) based on information from Vaughan et al. (1994) and Neill and Gunter (1994)
(4) based on information from MOEE (1992)

Table B-6 Estimated amortized capital costs for incinerators/energy from waste facilities

Province	# of Incinerators Facilities (1)	Annual Capacity	# of EFW Facilities (1)	Annual Capacity	Known Capital Costs (2)	Remaining Annual Capacity	Total Annual Capacity
Newfoundland	4	35,516	0	0		0	35,516
PEI	0	0	1	29,843		29,843	29,843
Nova Scotia	6	28,975	1	27,730		0	56,705
New Brunswick	0	0	0	0		0	0
Quebec	1	24,085	2	517,344		517,344	541,429
Ontario	0	0	5	276,900	$112,238,583	98,700	276,900
Manitoba	0	0	0	0		0	0
Saskatchewan	0	0	0	0		0	0
Alberta	0	0	0	0		0	0
British Columbia	4	22,500	1	235,000	$81,200,000	0	257,500
NWT	0	0	0	0		0	0
Yukon	0	0	0	0		0	0
Total Capacity	**15**	**111,076**	**10**	**1,086,817**	**$193,438,583**	**645,887**	**1,197,893**
Estimated Capital Costs per Tonne		(3)		(4)			
Low Estimate $/tonne		$24.00		$35.00			
Low Estimated Annualized Capital Costs		**$2,665,824**		**$22,606,045**	**$18,259,234**		**$43,531,103**
Medium Estimate $/tonne		$30.00		$43.00			
Medium Estimated Annualized Capital Costs		**$3,332,280**		**$27,773,141**	**$18,259,234**		**$49,364,655**
High Estimate $/tonne		$36.00		$52.00			
High Estimated Annualized Capital Costs		**$3,998,736**		**$33,586,124**	**$18,259,234**		**$55,844,094**

(1) based on information from Hickling (1994), Quebec, Vaughan et al. (1994) and Neill and Gunter (1994)
(2) based on information from RIS (1994) and MOEE (1992); EFW capital costs provided for Burnaby, B.C.; Peel, Ontario; SWARU, Ontario; and Victoria Hospital, Ontario
(3) based on information from Vaughan et al. (1994) and Neill and Gunter (1994); all capital costs amortized over 20 years at 7%
(4) based on information from MOEE (1992); all capital costs amortized over 20 years at 7%

Table B-7 Estimated operating costs for incinerators/energy from waste facilities including annualized capital costs

Province	# of Incinerators Facilities (1)	Annual Capacity (1)	# of EFW Facilities (1)	Annual Capacity (1)	Total Annual Capacity
Newfoundland	4	35,516	0	0	35,516
PEI	0	0	1	29,843	29,843
Nova Scotia	6	28,975	1	27,730	56,705
New Brunswick	0	0	0	0	0
Quebec	1	24,085	2	517,344	541,429
Ontario	0	0	5	276,900	276,900
Manitoba	0	0	0	0	0
Saskatchewan	0	0	0	0	0
Alberta	0	0	0	0	0
British Columbia	4	22,500	1	235,000	257,500
NWT	0	0	0	0	0
Yukon	0	0	0	0	0
Total Capacity	**15**	**111,076**	**10**	**1,086,817**	**1,197,893**
Estimated Operating Costs (3)		(3)		(4)	
Low Estimate $/tonne		$45.00		$72.00	
Low Estimated Operating Costs		**$4,998,420**		**$78,250,824**	**$83,249,244**
Medium Estimate $/tonne		$51.00		$81.00	
Medium Estimated Operating Costs		**$5,664,876**		**$88,032,177**	**$93,697,053**
High Estimate $/tonne		$57.00		$85.00	
High Estimated Operating Costs		**$6,331,332**		**$92,379,445**	**$98,710,777**

(1) based on information from Hickling (1994), Quebec, Vaughan et al. (1994) and Neill and Gunter (1994)
(2) based on information from RIS (1994) and MOEE (1992)
(3) based on information from Vaughan et al. (1994) and Neill and Gunter (1994) (average amortized capital cost of $21/tonne has been used)
(4) based on information from RIS (1994) and MOEE (1992) (average amortized capital cost of $43/tonne has been used)

Table B-8 Estimated capital costs of material recovery facilities

Province	# of MRF Facilities (1)	Amount of Recyclables Processed Annually (2)			Total
		Residential	IC&I	C&D (4)	
Newfoundland	2	2,872	25,655	330	28,857
PEI	1	1,896	11,490	0	13,386
Nova Scotia	11	9,074	48,829	0	57,903
New Brunswick	7	3,876	30,913	0	34,789
Quebec	15	227,806	1,350,194	0	1,578,000
Ontario	51	478,890	1,366,441	705,791	2,551,122
Manitoba	9	3,514	63,568	0	67,082
Saskatchewan	3	21,400	79,034	0	100,434
Alberta	5	17,597	150,630	56,190	224,417
British Columbia	39	100,798	411,836	508,188	1,020,822
NWT	1	51	2,211	991	3,253
Yukon	1	213	1,311	485	2,009
Total Capacity	145	867,987	3,542,112	1,271,975	5,682,074
Estimated Capital Costs		(3)	(5)	(5)	
Low Estimate $/tonne		$238.00	$238.00	$238.00	
Low Estimated Capital Costs		$206,580,906	$843,022,656	$302,730,050	**$1,352,333,612**
Medium Estimate $/tonne		$264.00	$264.00	$264.00	
Medium Estimated Capital Costs		$229,148,568	$935,117,568	$335,801,400	**$1,500,067,536**
High Estimate $/tonne		$291.00	$291.00	$291.00	
High Estimated Capital Costs		$252,584,217	$1,030,754,592	$370,144,725	**$1,653,483,534**

(1) internal information
(2) based on waste diversion estimates (representing materials processed at public and private MRFs)
(3) capital costs based on Ontario averages, RIS (1994)
(4) Asphalt and concrete have been removed from the diversion numbers. Wood waste is included in the C&D figures.
(5) Capital costs developed for municipal MRFs have been applied to MRFs for IC&I and C&D recyclables.

Table B-9 Estimated annualized capital costs of material recovery facilities

Province	# of MRF Facilities (1)	Amount of Recyclables Processed Annually (2)			Total
		Residential	IC&I	C&D (4)	
Newfoundland	2	2,872	25,655	330	28,857
PEI	1	1,896	11,490	0	13,386
Nova Scotia	11	9,074	48,829	0	57,903
New Brunswick	7	3,876	30,913	0	34,789
Quebec	15	227,806	1,350,194	0	1,578,000
Ontario	51	478,890	1,366,441	705,791	2,551,122
Manitoba	9	3,514	63,568	0	67,082
Saskatchewan	3	21,400	79,034	0	100,434
Alberta	5	17,597	150,630	56,190	224,417
British Columbia	39	100,798	411,836	508,188	1,020,822
NWT	1	51	2,211	991	3,253
Yukon	1	213	1,311	485	2,009
Total Capacity	145	867,987	3,542,112	1,271,975	5,682,074
Estimated Capital Costs		(3)	(5)	(5)	
Low Estimate $/tonne		$27.96	$27.96	$27.96	
Low Estimated Capital Costs		$24,268,917	$99,037,452	$35,564,421	**$158,870,789**
Medium Estimate $/tonne		$31.01	$31.01	$31.01	
Medium Estimated Capital Costs		$26,916,277	$109,840,893	$39,443,945	**$176,201,115**
High Estimate $/tonne		$34.18	$34.18	$34.18	
High Estimated Capital Costs		$29,667,796	$121,069,388	$43,476,106	**$194,213,289**

(1) internal information
(2) based on waste diversion estimates
(3) amortized over 20 years at 10% interest; capital costs based on Ontario averages, RIS (1994)
(4) Asphalt and concrete have been removed from the diversion numbers. Wood waste is included in the C&D figures.
(5) Capital costs developed for municipal MRFs have been applied to MRFs for IC&I and C&D recyclables.

Table B-10 Estimated operating costs of material recovery facilities including annualized capital costs

Province	# of Residential MRF Facilities (1)	Amount of Recyclables Processed Annually (tonnes) (2)			Total
		Residential	IC&I	C&D (6)	Tonnes
Newfoundland	2	2,872	25,655	330	28,857
PEI	0	1,896	11,490	0	13,386
Nova Scotia	11	9,074	48,829	0	57,903
New Brunswick	7	3,876	30,913	0	34,789
Quebec	15	227,806	1,350,194	0	1,578,000
Ontario	51	478,890	1,366,441	705,791	2,551,122
Manitoba	9	3,514	63,568	0	67,082
Saskatchewan	3	21,400	79,034	0	100,434
Alberta	5	17,597	150,630	56,190	224,417
British Columbia	39	100,798	411,836	508,188	1,020,822
NWT	unknown	51	2,211	991	3,253
Yukon	unknown	213	1,311	485	2,009
Total Capacity	142	867,987	3,542,112	1,271,975	5,682,074
Estimated Operating Costs (3)		(4)	(5)	(5)	
Low Estimate $/tonne		$83.00	$115.00	$75.00	
Low Estimated Operating Costs		$72,042,921	$407,342,880	$95,398,125	**$574,783,926**
Medium Estimate $/tonne		$92.00	$125.00	$80.00	
Medium Estimated Operating Costs		$79,854,804	$442,764,000	$101,758,000	**$624,376,804**
High Estimate $/tonne		$102.00	$135.00	$85.00	
High Estimated Operating Costs		$88,534,674	$478,185,120	$108,117,875	**$674,837,669**

(1) RIS inhouse files
(2) based on waste diversion estimates
(3) includes capital amortization costs amortized over 20 years at 10%
(4) operating costs based on Ontario averages, RIS (1994)
(5) Operating costs include revenues and profits based on Ontario data (MOEE, 1994).
(6) Does not include concrete and asphalt diversion. Wood waste is included in the C&D figures.

Table B-11 Estimated capital costs of centralized windrow composting facilities

Province	# of Windrow Composting Facilities (1)	Total Annual Capacity Tonnes (2) # of facilities falling in the range of			Total
		0-5,000 tonnes/yr	5,001-25,000 tonnes/yr	25,001 + tonnes/yr	
Newfoundland	1	1			1
PEI	2	2			2
Nova Scotia	2	1	1		2
New Brunswick	1	1			1
Quebec	19	18	1		19
Ontario	37	26	9	2	37
Manitoba	6	6			6
Saskatchewan	2	2			2
Alberta	8	7	1		8
British Columbia	7	4	3		7
NWT					0
Yukon	1	1			1
Total Capacity	86	69	15	2	86
Total Capital Costs					
Low Estimates		$595,000	$1,000,000	$15,800,000	
Low Estimated Capital Costs		$41,055,000	$15,000,000	$31,600,000	**$87,655,000**
Medium Estimates		$787,500	$2,000,000	$18,850,000	
Medium Estimated Capital Costs		$54,337,500	$30,000,000	$37,700,000	**$122,037,500**
HIgh Estimates		$980,000	$6,000,000	$21,900,000	
High Estimated Capital Costs		$67,620,000	$90,000,000	$43,800,000	**$201,420,000**

(1) as reported by the Canadian Composting Council (1993), and confidential
(2) Each leaf and yard waste composting facility falls into one of three ranges. Capacity is based on annual amount received.
(3) capital costs as reported in GVRD (1993) and Nova Scotia (1993)

Table B-12 Estimated annualized capital costs of centralized windrow composting facilities

Province	# of Windrow Composting Facilitites (1)	Total Annual Tonnes Received (2) Individual facilities falling in the range of			Total
		0-5,000 tonnes/yr	5,001-25,000 tonnes/yr	25,001 + tonnes/yr	
Newfoundland	1	894			894
PEI	2	336			336
Nova Scotia	2	34	7,000		7,034
New Brunswick	1	630			630
Quebec	19	10,480	10,000		20,480
Ontario	37	30,541	79,816	121,986	232,343
Manitoba	6	874			874
Saskatchewan	2	96			96
Alberta	8	1,823	14,896		16,719
British Columbia	7	1,998	33,616		35,614
NWT					0
Yukon	1	50			50
Total Capacity	**86**	**47,756**	**145,328**	**121,986**	**315,070**
unit capital cost/tonne (3)					
Low Estimate $/tonne		29	19	28	
Low Estimated Annualized Capital Costs		**$1,384,924**	**$2,761,232**	**$3,415,608**	**$7,561,764**
Medium Estimate $/tonne		$38	$34	$34	
Medium Estimated Annualized Capital Costs		**$1,814,728**	**$4,941,152**	**$4,147,524**	**$10,903,404**
High Estimate $/tonne		$47	$38	$39	
High Estimated Annualized Capital Costs		**$2,244,532**	**$5,522,464**	**$4,757,454**	**$12,524,450**

(1) As reported by the Canadian Composting Council (1993) and confidential, all facilities reported in 1992 are assumed to be windrow composting facilities.

(2) Each leaf and yard waste composting facility falls into one of three ranges. The windrow compost facility capacity estimates include compostible materials (such as sewage sludge) which are not typically considered part of the municipal waste stream.

(3) amortized over 5 and 10 years at 7% (based on GVRD assumptions); capital costs as reported in GVRD (1993C) and Nova Scotia (1993) reports

Table B-13 Estimated operating costs of centralized windrow composting facilities (no capital allowance)

Province	# of Windrow Composting Facilities (1)	Total Annual Tonnes Received (2) Individual facilities falling in the range of			Total
		0-5,000 tonnes/yr	5,001-25,000 tonnes/yr	25,001 + tonnes/yr	
Newfoundland	1	894			894
PEI	2	336			336
Nova Scotia	2	34	7,000		7,034
New Brunswick	1	630			630
Quebec	19	10,480	10,000		20,480
Ontario	37	30,541	79,816	121,986	232,343
Manitoba	6	874			874
Saskatchewan	2	96			96
Alberta	8	1,823	14,896		16,719
British Columbia	7	1,998	33,616		35,614
NWT					0
Yukon	1	50			50
Total Capacity	**86**	**47,756**	**145,328**	**121,986**	**315,070**
unit capital cost/tonne (3)					
Low estimate $/tonne		$16	$16	$16	
Low Estimated Operating Costs		**$764,096**	**$2,325,248**	**$1,951,776**	**$5,041,120**
Medium estimate $/tonne		$21	$21	$21	
Medium Estimated Operating Costs		**$1,002,876**	**$3,051,888**	**$2,561,706**	**$6,616,470**
HIgh estimate $/tonne		$26	$26	$26	
High Estimated Operating Costs		**$1,241,656**	**$3,778,528**	**$3,171,636**	**$8,191,820**

(1) As reported by the Canadian Composting Council (1993) and confidential; all facilities reported in 1992 are assumed to be windrow composting facilities.

(2) Each leaf and yard waste composting facility falls into one of three ranges. The windrow compost facility capacity estimates include compostible materials (such as sewage sludge) which are not typically considered part of the municipal waste stream.

(3) operating costs as reported in GVRD (1993C)

Table B-14 Estimated operating costs of centralized windrow composting facilities including annualized capital costs

Province	# of Windrow Composting Facilitites (1)	Total Annual Tonnes Received (2) Individual facilities falling in the range of			Total
		0-5,000 tonnes/yr	5,001-25,000 tonnes/yr	25,001 + tonnes/yr	
Newfoundland	1	894			894
PEI	2	336			336
Nova Scotia	2	34	7,000		7,034
New Brunswick	1	630			630
Quebec	19	10,480	10,000		20,480
Ontario	37	30,541	79,816	121,986	232,343
Manitoba	6	874			874
Saskatchewan	2	96			96
Alberta	8	1,823	14,896		16,719
British Columbia	7	1,998	33,616		35,614
NWT					0
Yukon	1	50			50
Total Capacity	**86**	**47,756**	**145,328**	**121,986**	**315,070**
unit capital cost/tonne (3)					
Low estimate $/tonne		$45	$35	$44	
Low Estimated Operating Costs		**$2,149,020**	**$5,086,480**	**$5,367,384**	**$12,602,884**
Medium estimate $/tonne		$59	$55	$55	
Medium Estimated Operating Costs		**$2,817,604**	**$7,993,040**	**$6,709,230**	**$17,519,874**
HIgh estimate $/tonne		$73	$64	$65	
High Estimated Operating Costs		**$3,486,188**	**$9,300,992**	**$7,929,090**	**$20,716,270**

(1) As reported by the Canadian Composting Council (1993) and confidential; all facilities reported in 1992 are assumed to be windrow composting facilities.
(2) Each leaf and yard waste composting facility falls into one of three ranges. The windrow compost facility capacity estimates include compostible materials (such as sewage sludge) which are not typically considered part of the municipal waste stream.
(3) operating costs as reported in GVRD (1993 C)

Table B-15 Estimated operating costs for backyard composters including annualized capital costs

Province	# of Backyard Composting Units (1)	Diversion Rate (2)	Operating Costs (3)	
		(assumes 1 composter diverts 0.135 tonne/yr)	Low Estimates (@ $25/tonne)	High Estimates (@ $45/tonne)
Newfoundland	unknown	unknown	unknown	unknown
PEI	unknown	unknown	unknown	unknown
Nova Scotia	unknown	unknown	unknown	unknown
New Brunswick	100	14	338	608
Quebec	10,961	1,480	36,993	66,588
Ontario	669,283	90,353	2,258,830	4,065,894
Manitoba	3,977	537	13,422	24,160
Saskatchewan	unknown	unknown	unknown	unknown
Alberta	unknown	unknown	unknown	unknown
British Columbia	42,837	5,783	144,575	260,235
NWT	unknown	unknown	unknown	unknown
Yukon	unknown	unknown	unknown	unknown
Total	**727,158**	**98,166**	**2,454,158**	**4,417,485**

(1) As reported by Environment Canada; not all provinces reported the use/promotion of backyard composters in their communities.
(2) Diversion rate is based on 169 kg/household/year organics diverted at an 80% participation rate.
(3) Based on GTA report (MOEE 1994) which includes the capital costs of a composter amortized over a 10-year period at 10%.

Table B-16 Capital costs of waste collection trucks

Management Method	Tonnes Collected	Annual Tonnes Per Truck (1)	Estimated Number of Trucks	Total Annual Cost (2)
Collection for Landfill	22,064,511	3,463	6,372	$637,150,188
Collection for Compost	315,070	1,500	210	$21,004,667
Collection for Incineration	1,197,893	3,463	346	$34,591,193
Municipal Collection for Recycling	867,987	1,500	579	$57,865,800
IC&I and C&D Collection for Recycling (3)	8,976,441	1,500	5,984	$598,429,400
Total	**33,421,902**		**13,490**	**$1,349,041,247**

(1) based on RIS in-house data determining the annual tonnes of waste/recyclables collected per truck
(2) based on assumptions that each truck costs $100,000 (RIS in-house information)
(3) includes costs to collect asphalt and concrete (4,162,353 tonnes)
NOTE: The total tonnage does not accurately represent generation rates because ash residue (341,367 tonnes) from incineration appears in both the incineration and the landfill estimates.

Table B-17 Waste collection costs

Management Method	Tonnes Collected	Total Annual Cost (1)	
		$/tonne	**Total**
Collection for Landfill	22,064,511	$47	$1,037,032,017
Collection for Compost	315,070	$73	$23,000,110
Collection for Incineration	1,197,893	$47	$56,300,971
Municipal Collection for Recycling	867,987	$101	$87,666,687
IC&I and C&D Collection for Recycling(2)	8,976,441	$50	$448,822,050
Total (3)	**33,421,902**		**$1,652,821,835**

(1) costs from GTA 3Rs analysis (MOEE 1994)
(2) includes costs to collect asphalt and concrete (4,162,353 tonnes)
(3) The total tonnage does not include backyard composting.
NOTE: The total tonnage does not accurately represent generation rates because ash residue (341,367 tonnes) from incineration appears in both the incineration and landfill estimates.

Table B-18 Estimated employment in the Canadian waste management industry

		Total Generation	Total Employees(1)	Municipal Employees (2)	Private Employees (2)	Combined (municpal and private) (2)
Newfoundland	Residential	166,980	106	50%	43%	7%
	IC&I	330,611	209		100%	
	Total	**497,591**	**315**	**53**	**255**	**7**
Nova Scotia	Residential	353,687	224	50%	43%	7%
	IC&I	368,265	233		100%	
	Total	**721,952**	**457**	**112**	**330**	**15**
New Brunswick	Residential	237,291	150	50%	43%	7%
	IC&I	361,037	229		100%	
	Total	**598,328**	**379**	**75**	**294**	**10**
PEI	Residential	35,231	22	50%	43%	7%
	IC&I	74,442	47			100%
	Total	**109,673**	**69**	**11**	**10**	**49**
Quebec	Residential	2,592,252	1,641	44%	52%	4%
	IC&I	5,435,709	3,440		100%	
	Total	**8,027,961**	**5,081**	**722**	**4,293**	**66**
Ontario	Residential	4,332,070	2,742	49%	38%	13%
	IC&I	9,186,812	5,814		100%	
	Total	**13,518,882**	**8,556**	**1,343**	**6,865**	**347**
Manitoba	Residential	464,764	294	43%	33%	24%
	IC&I	834,675	528		100%	
	Total	**1,299,439**	**822**	**126**	**626**	**71**
Saskatchewan	Residential	437,923	277	43%	33%	24%
	IC&I	822,288	520		100%	
	Total	**1,260,211**	**798**	**118**	**613**	**67**
Alberta	Residential	654,268	414	43%	33%	24%
	IC&I	2,391,413	1,514		100%	
	Total	**3,045,681**	**1,928**	**177**	**1,652**	**99**
British Columbia	Residential	1,267,583	802	40%	47%	13%
	IC&I	2,757,888	1,745		100%	
	Total	**4,025,471**	**2,548**	**321**	**2,123**	**104**
Northwest Territories and Yukon	Residential	8,952	6	50%	50%	0
	IC&I	64,560	41		100%	
	Total	**73,512**	**47**	**3**	**44**	
		Subtotal (3)		**3,061**	**17,104**	**834**
		Total (4)	**20,999**	**3,478**	**17,522**	

(1) The number of employees is calculated using the formula of 1,580 tonnes processed on average per employee. This number is estimated using information generated by the Ontario Waste Management Association (OWMA, 1994) and extrapolated to other jurisdictions.

(2) The proportion of municipal sector, private sector and combined sectors involved in waste management in each province is based on information collected in a survey by Statistics Canada (1993).

(3) The subtotal distinguishes between municipal sector, private sector and combined sectors (municipal and private sectors working together).

(4) The total assumes that, of the combined category, half of the employees work in the public sector and the other half work in the private sector, which has been added to each respective category.

Table B-19 Range of estimated annual waste management costs

Management Method	Tonnes	Total Annual Cost		
		Low Estimate	Medium Estimate	High Estimate
Landfill (including gas recovery)	22,064,511	$430,541,424	$650,589,654	$870,637,883
Collection for Landfill		$1,037,032,017	$1,037,032,017	$1,037,032,017
EFW (net of revenue)	1,086,817	$78,250,824	$88,032,177	$92,379,445
Incineration	111,076	$4,998,420	$5,664,876	$6,331,332
Collection for Incineration		$56,300,971	$56,300,971	$56,300,971
Recycling - Municipal (net of revenue)	867,987	$72,042,921	$79,854,804	$88,534,674
Municipal Collection for Recycling		$87,666,687	$87,666,687	$87,666,687
Recycling - IC&I and C&D (net of revenue)	4,814,088	$502,741,005	$544,522,000	$586,302,995
IC&I and C&D Collection for Recycling	4,162,353	$448,822,050	$448,822,050	$448,822,050
Compost (windrow)	315,070	$12,602,884	$17,519,874	$20,716,270
Collection for Compost		$23,000,110	$23,000,110	$23,000,110
Backyard Composting	98,167	$2,454,158	$3,435,822	$4,417,485
Total	**33,520,069**	**$2,756,453,471**	**$3,042,441,041**	**$3,322,141,919**

NOTE: The total tonnage does not accurately represent generation rates because ash residue (341,367 tonnes) from incineration appears in both the incineration and landfill generation estimates.

Appendix C

Background to Energy Estimates

1 Introduction

1.1 Background

Energy issues are central to the analysis of solid waste management. This is because energy is used in waste management processes and there is an energy component within waste itself. The use of different approaches to solid waste management will have very different implications for the use or production of energy. These implications need to be considered in the context of present concerns regarding the efficiency of processes in Canada as well as from the perspective of energy and environmental policies that are emerging as local, regional, national and international issues. A number of issues need to be considered, including:

- the efficient use of energy in Canada,
- emerging policy on greenhouse gas reduction,
- energy implications of recycling and reduction programs,
- recovery of energy from waste, and
- technology needs related to the commercialization of energy related programs.

1.2 Approach

There is no standardized approach to data collection in the private or public Canadian waste management sector. For the purpose of estimating the energy aspects of the system, it is necessary to develop typical values based on related research and to apply these typical values to the Canadian system, usually based on tonnage estimates. For these reasons, energy estimates must be developed by the application of assumptions to the broader system, and they cannot be expected to have a high degree of accuracy at a disaggregated level. For the purpose and scope of this study, the energy estimates are accurate enough to provide planning guidance and to help us to understand the rapidly changing system as we increase the collection of recyclables and reduce the quantities generated at source.

- **Energy used in the collection and processing of waste** has been estimated by developing typical energy profiles for the different activities in the waste management sector: collection, transferring (including incineration material handling), landfilling and recyclable processing.
- **Energy content of waste** has been estimated by applying the results of waste profile studies to the volumes of waste managed in the system. The energy content is generally considered to be directly associated with the carbon content of the waste. This carbon content provides the energy that is recoverable from incineration, landfill gas collection or composting.
- **Energy saved through recycling and source reduction** is derived from the literature based on partial life-cycle analyses, with recovered products being input into the production of products such as steel, aluminum, glass, paper and plastic. The energy saved by using recycled waste in the processes is applied to the mass estimates of recyclables diverted into the production processes.

1.3 Energy Expended in Solid Waste Management

Energy input is a factor in the evaluation of the programs which are developed for waste management. Although the energy component may not be identified in the process, the development of competitive bids or the costing of program changes must always account for the input of energy either as part of the processing cost or as a fuel component related to collection, transport or processing. Yet there has not been any systematic collection of energy consumption data within the Canadian solid waste management sector, and the development of energy estimates has required interpretation and assumptions in order to provide rough estimates of energy consumption. This section does, however, set a context for the application of energy to waste management activities and attempts to evaluate energy consumption in the principle sub-activities common to most types of solid waste management activities.

2 *Energy Expended in Waste Collection*

2.1 General

For the purpose of developing energy estimates, collection is defined as the activities that pick up waste from the source and deliver it to a local destination, which could be a transfer station, a landfill or combustion facility, a waste processing facility or other site. The delivery of the waste to its destination is done by the same truck that picks the waste up from the generator/ household. It should be noted that management systems which feature depot collection generally do not attribute energy consumption to collection activities, because most of the energy is expended by the generators themselves. In fact, this type of system will require a high energy component per unit of waste collected, but that energy will be attributed to personal vehicles either on single-purpose trips or as part of a route incorporating of other personal activities. This external energy input has not been included as part of the waste management system.

In IC&I waste collection, there is a variety of different collection systems related to waste characteristics and volume. Collection efficiencies of these systems vary. For this reason, energy consumption for IC&I is considered to average at a collection efficiency that is slightly lower than for residential garbage collection.

There is an energy penalty for the collection of residential recyclables compared to the collection of residential garbage. This penalty is related to the average weight of garbage versus recyclables collected per household, as well as to the simpler collection process required for collecting garbage compared to the longer sorting process required for recyclables. Pickup efficiency is also improved by the compaction of garbage by the truck, permitting more households to be served before a trip to a disposal or a transfer station is required. As more and more recyclable materials are targetted and diverted to recyclable collection, the energy and collection cost implications for these streams change.

2.2 Residential Garbage Collection

The characteristics of the appropriate vehicle for garbage collection are determined by the quantity and nature of the waste and the distances that are traveled during collection. In the case of municipal high-density or suburban garbage collection, typically a "packer" truck is selected as the most cost effective collection vehicle. The chief considerations in determining the best approach would depend on the following:

- labour cost based on the number of staff required to operate the vehicle,
- fuel consumption (direct energy consideration),
- compaction ratio (energy and load size),
- maintenance cost and down time,
- load capacity,
- collection efficiency (average time per stop),
- distance to drop from collection area,

- urban/rural density of collection area, and
- length of working day.

Typical models for predicting fuel consumption or emissions cannot be applied to transportation vehicles because of the unusual driving requirements involved in waste collection. Garbage collection trucks are continually starting and stopping, with short distances traveled between stops. Also, packers are heavy trucks, and their fuel consumption is higher than for most transportation vehicles.

Information has been acquired from a number of sources, and a typical collection scenario has been developed as a basis for estimating energy consumption. Specific applications of these estimates to different collection scenarios have been developed to take into account different operating and collection activities, such as increased energy efficiency resulting from waste compaction and high-density collection routes. table C-1 illustrates the effect of vehicle type and collection density on energy input requirements for mixed refuse collection.

2.3 Residential Recyclables Collection

As recycling programs have developed, the requirements and economics of collection have resulted in the development of specialized collection vehicles designed to support specific recycling programs. There are many types of vehicles, and many are specifically designed for each application. Typically, dry recyclables may be collected in compartmentalized trucks in which separate streams are segregated at the collection point. There are a large number of different (customized) approaches being taken, and as per-household collection quantities increase, the collection energy efficiency improves. This has an inverse effect for the garbage collection system (see section C.9 for further discussion).

The labour and energy applied to recyclables collection, unlike garbage collection, has implications for the further segregation and processing of the materials. Collection of recyclables provides a tradeoff in energy consumption, and the processing component can be unique to any given municipal location and will be dependent on several factors including:

Table C-1 Collection vehicle characteristics for residential garbage collection

Vehicle Characteristics	Typical Collection	Low Unit Collection	High Unit Collection
Truck Capacity (cubic metres)	21.0	15.0	27.0
Daily Collection (tonnes)	13.5	8.0	15.0
Compaction Ratio	3:1	none	3:1
Area Characteristics	Medium Density (suburban)	Low Density (rural)	High Density (multi-family/urban)
Diesel Consumption (litres/ 100 km)	78	50	80
Daily Fuel Consumption (litres)	58	48	60
Fuel Allocation (litres/tonne waste)	4.3	6.0	4.0
Energy Input (MJ/tonne)	167	230	154
CO_2 Emissions (kg/tonne)	11.8	16.3	10.9

- list of eligible recyclables,
- cost of sorting after collection versus added cost of increased sorting during collection
- effect on collection efficiency (both labour and fuel consumption), and
- issues listed above for residential garbage collection.

The assumptions used to develop energy estimates for residential recyclables collection are summarized in table C-2.

2.4 *Industrial, Commercial and Institutional Waste Collection*

No useful data were found for IC&I collection. Projections were developed by comparing typical IC&I collection activities to residential garbage collection. Collection of garbage and recyclables from IC&I locations was considered to have similar characteristics with a slightly less efficient collection basis than residential garbage collection in a reasonably efficient suburban density environment. The efficiency based on larger load size was reduced by the longer distances between collection points, as these collections are frequently distributed among a number of private sector waste management companies. The differences are based on an average of 5.0 tonnes/km collection compared to 4.5 tonnes/km for residential (GVRD Solid Waste Management Plan—Stage II). Assumptions used for the energy analysis are summarized in table C-3.

Table C-2 Collection vehicle characteristics for collection of residential recyclables

Vehicle Characteristics	Typical Collection	Low Unit Collection	High Unit Collection
Truck Capacity (cubic metres)	11.0	15.0	27.0
Daily Collection (tonnes)	3.1	2.0	5.0
Compaction Ratio	none	none	none
Area Characteristics	Medium Density (suburban)	Low Density (rural)	High Density (multi-family/urban)
Diesel Consumption (litres/ 100 km)	47	40	55
Daily Fuel Consumption (litres)	38	37	53
Fuel Allocation (litres/tonne waste)	12.3	18.5	10.6
Energy Input (MJ/tonne)	475	716	410
CO_2 Emissions (kg/tonne)	33.6	50.6	29.0

Table C-3 Energy input for waste collection

Waste Source	Mixed Waste for Landfill or Combustion (MJ/tonne collected)	Recyclable Collection (MJ/tonne collected)
Residential	167	475
IC&I	186	186
C&D	84	84

2.5 Construction and Demolition Waste Collection

C&D waste management involves a variety of activities, with waste collection and disposal services provided by a wide array of private sector operators. It is expected that typical C&D waste collection will consist of larger, non-compacted loads which are direct hauled to local sites for segregation, diversion and disposal. Energy input and CO_2 emissions were arbitrarily set at 50% of the rate of residential garbage collection, as illustrated in table C-3.

To provide energy input estimates for the provincial and national level, the typical case has been used as the basis of extrapolation to the waste quantity estimates provided in chapter 2 of this document. This does not provide a completely accurate and technically defensible projection but it does provide a reasonable basis for determining the overall energy applied to the collection of waste. The data available to refine these estimates can better define the ranges of collection energy usage but will still not be suitable for accurate extrapolation. Energy input estimates for waste collection activities are presented for the national level in table C-4 and for the individual provinces and territories in appendix D .

3 Greenhouse Gas Emissions Rates for Waste Collection Activities

Since most of the collection activity is done by diesel vehicles, the development of estimates for greenhouse gas emissions is a direct outcome of the combustion process, which effectively converts all of the carbon in the fuel into CO_2. There is also a small contribution to the greenhouse effect from N_2O and CH_4 (methane) which are emitted at very low levels as contaminants. Each litre of diesel creates 2.73 kg of CO_2 equivalents (calculated from Jacques, 1990). Since diesel fuel usage provided the basis for the energy input estimates, the same unit usage of diesel was converted to provide CO_2 emission estimates (table C-5).

4 Energy Expended in Waste Transfer, Handling and Transport to Final Destination

As waste management systems evolve, they are frequently made more cost effective by the development of central transfer facilities which take waste from collection vehicles and transport the waste to the next management process in a more cost effective manner. Vehicles used to transport waste from transfer stations are optimized based on the volume of waste requiring transport and the distance to the destination. The optimization of cost is invariably accompanied by a reduction in fuel or energy input per tonne of waste transported.

The energy utilization for the transfer activities also includes the energy required to operate the transfer process, which can include both electrical equipment and vehicles. Examples of equipment would be loaders, compactors, waste trailers, cabs, containers, and roll-on-roll-off equipment. A summary of energy and CO_2 estimates associated with waste transfer is presented in table C-6.

This analysis includes both the operation of the transfer station as well as the transit to the disposal, recycling or incineration site. The largest energy component comes from the vehicle operation and the mobile equipment used to move waste on-site. Electrical power input for operation would increase power consumption by 15 to 20%. Table C-7 provides operating information for three typical transfer station operations. The three types of transfer station range from a small rural (low volume) station to a very large urban station used to transfer large volumes of waste. The medium size was selected to represent the typical or average transfer station. As in the collection issue, there is a difficulty trying to extrapolate energy requirements from these figures, and the following assumptions have been made to estimate energy input to transfer station operation in Canada:

Table C-4 **Estimates of energy consumption and carbon dioxide emission for collection of wastes in Canada, 1992**

	Energy Inputs to Waste Collection			Total	
Waste	**Tonnes Generated ($x10^6$)**	**Tonnes Combusted ($x10^6$)**	**Tonnes Composted ($x10^6$)**	**Tonnes Recycled ($x10^6$)**	**Tonnes Landfilled ($x10^6$)**
Waste Source					
Residential	0.54	0.64	0.32	0.87	8.72
IC&I	12.66	0.22	0.10	3.54	8.80
C&D	9.98	-	-	5.43	4.54
Total	**33.18**	**0.86**	**0.41**	**9.84**	**22.06**
Collection Energy Input Rates	**Generated (MJ/tonne)**	**Combusted (MJ/tonne)**	**Composted (MJ/tonne)**	**Recycled (MJ/tonne)**	**Landfilled (MJ/tonne)**
Rate per tonne					
* Residential	N/A	167.0	55.1	475.0	167.0
IC&I	N/A	186.0	186.0	186.0	186.0
C&D	N/A	0.0	0.0	84.0	84.
Collection Energy Inputs	**Generated (gigajoules)**	**Combusted (gigajoules)**	**Composted (gigajoules)**	**Recycled (gigajoules)**	**Landfilled (gigajoules)**
Energy	**Total Energy**				
Residential	1,992,695	106,916	17,404	412,292	1,456,083
IC&I	2,354,642	40,236	18,122	658,833	1,637,451
C&D	838,006	0	0	456,483	381,523
Total	**5,185,343**	**147,151**	**35,526**	**1,527,608**	**3,475,057**
Grand total in gigajoules					**5,185,343**
Collection CO_2 Emissions	**Generated (kilotonnes)**	**Combusted (kilotonnes)**	**Composted (kilotonnes)**	**Recycled (kilotonnes)**	**Landfilled (kilotonnes)**
Total Emissions	**Total CO_2**				
Residential	143	8	4	29	103
IC&I	166	3	1	46	116
C&D	59	0	0	32	27
Total	**369**	**10**	**5**	**108**	**246**
Total CO_2 Emissions in kilotonnes					**369**

Table C-5 Greenhouse gas emissions for waste collection

Waste Source	Mixed Waste for Landfill or Combustion (kg CO_2/tonne collected)	Recyclable Collection (kg CO_2/tonne collected)
Residential	11.8	33.6
IC&I	13.2	13.2
C&D	5.9	5.9

Table C-6 Summary of national energy and carbon dioxide emission estimates for waste transfer

Total waste to landfill or combustion—residential	9.36	tonnes x 106
Total waste to landfill or incineration—IC&I	9.02	tonnes x 106
Estimate of transfer quantity	7.35	tonnes x 106
Diesel fuel input for transport and processing	1.25	litres/tonne
Transportation energy input	48.4	MJ/tonne
Processing energy input	9.7	MJ/tonne
Transportation energy input—total	356,000	gigajoules
Processing energy input—total	71,000	gigajoules
Total energy inputs to transfer	427,000	gigajoules
Transportation CO_2 generation rate	3.42	kg/tonne
Processing CO_2 generation rate	0.29	kg/tonne
Transportation CO_2 emissions—total	25	kilotonnes
Processing CO_2 emissions—total	2	kilotonnes
Total CO_2 emissions from transfer	27	kilotonnes

- The source of electrical power is assumed to be the national blend. This blend generates 1,772 petajoules (PJ) of energy across Canada, and the thermal components of the blend produce CO_2 emissions of 94,424 kilotonnes (Canada's National Report on Climate Change, 1994). This translates to an average rate of 0.05 kg CO_2 per megajoule (MJ) of electrical energy.
- It is assumed that 40% of the waste is shipped to final destination through transfer stations, or inversely that 60% of the waste collected is transported directly to its final destination. This assumption was used to apply energy and emission factors to total waste quantities in order to obtain national estimates.
- The assumption of 40% waste being processed through transfer stations is higher than the Canadian average. In Quebec, for example, only 15% of waste is processed through transfer stations. Just the Quebec figure results in an overstatement of the Canadian estimates by 64,000 GJ of input energy and 4 kt of CO_2 emissions. Since transfer activities reduce overall energy input requirements by improving system efficiency, this implies that the collection efficiencies

Table C-7 Energy input to municipal waste transfer facilities

Transfer Station Assumptions		**Transfer Type 1** (low volume)	
Typical transit truck capacity		40	tonnes
Typical Round Trip		50	km
Fuel Usage		2	miles/gallon
		0.85	km/l
		58.80	l
		1.47	l/tonne of waste
Energy input (transportation)		56.68	MJ/tonne
Additional energy for operation		20%	
Total energy input		68.01	MJ/tonne
CO_2 emissions	Transportation	4.01	kg/tonne
	Electrical	0.34	kg/tonne
	Total CO_2	4.35	kg/tonne

Transfer Station Assumptions		**Transfer Type 2** (medium volume)	
Typical transit truck capacity		60	tonnes
Typical round trip		80	km
Fuel usage		2.5	miles/gallon
		1.06	km/l
		75.27	l
		1.25	l/tonne
Energy input (transportation)		48.36	MJ/tonne
Additional energy for operation (20 % of transportation)		9.67	MJ/tonne
Total energy input		58.04	MJ/tonne
CO_2 emissions	Transportation	3.42	kg/tonne
	Operation	0.29	kg/tonne
	Total CO_2	3.71	kg/tonne

Transfer Station Assumptions		**Transfer Type 3** (high volume)	
Typical transit truck capacity		100	tonnes
Typical round trip		120	km
Fuel usage		2	miles/gallon
		0.85	km/l
		141.13	l
		1.41	l/tonne
Energy input (transportation)		54.41	MJ/tonne
Additional energy for operation		15%	
Total energy input		62.57	MJ/tonne
CO_2 emissions	Transportation	3.85	kg/tonne
	Electrical	0.24	kg/tonne
	Total CO_2	4.10	kg/tonne

Table C-8 Energy input and carbon dioxide emissions for waste transfer in Canada, 1992

Energy Inputs to Waste Transfer				Total	
Waste	**Tonnes Transferred ($x10^6$)**	**Tonnes Combusted ($x10^6$)**	**Tonnes Composted ($x10^6$)**	**Tonnes Recycled ($x10^6$)**	**Tonnes Landfilled ($x10^6$)**
Waste Source					
Residential	3.74	0.26	0.00	0.00	3.49
IC&I	3.61	0.09	0.00	0.00	3.52
C&D	0.00	0.00	0.00	0.00	0.00
Total	**7.35**	**0.34**	**0.00**	**0.00**	**7.01**
Process & Transport Energy Input Rates	**Transferred (MJ/tonne)**	**Combusted (MJ/tonne)**	**Composted (MJ/tonne)**	**Recycled (MJ/tonne)**	**Landfilled (MJ/tonne)**
Rate per tonne					
Residential	N/A	58.0	0.0	0.0	58.0
IC&I	N/A	58.0	0.0	0.0	58.0
C&D	N/A	0.0	0.0	0.0	0.0
Process & Transport Energy Inputs	**Generated (gigajoules)**	**Combusted (gigajoules)**	**Composted (gigajoules)**	**Recycled (gigajoules)**	**Landfilled (gigajoules)**
Energy	**Total Energy**				
Residential	217,247	14,861	0	0	202,387
IC&I	209,368	5,021	0	0	204,347
C&D	0	0	0	0	0
Total	**426,615**	**19,882**	**0**	**0**	**406,734**
Grand total in gigajoules 426,615					
Process & Transport CO_2 Emissions	**Generated (kilotonnes)**	**Combusted (kilotonnes)**	**Composted (kilotonnes)**	**Recycled (kilotonnes)**	**Landfilled (kilotonnes)**
Total Emissions	**Total CO_2**				
Residential	14	1	0	0	13
IC&I	13	0	0	0	13
C&D	0	0	0	0	0
Total	**27**	**1**	**0**	**0**	**26**
Total CO_2 Emissions in kilotonnes					**27**

would be lower in those regions with lower transfer relative volumes. Instead of adjusting up the collection factors to compensate for lower transfer factors, the 40% figure was maintained with the understanding that transfer estimates may be overstated by 15 to 20%; collection volumes would be understated by a similar volume, which would represent about 1% of the total collection estimates for energy input and CO_2 emissions.

- A medium volume (average) transfer station results in an energy input of 58 MJ per tonne and CO_2 emissions of 3.71 kg per tonne, based on both transportation to final disposal and internal electrical energy usage.
- Transfer stations are used for residential and IC&I waste collection but not for C&D waste collection.

Applying these rates to the Canadian estimates of waste transportation through transfer stations would result in the energy and greenhouse gas emission values for the transfer component presented in table C-8. To provide these projections on a provincial basis would require that provincial energy mix be applied and that the relative amount of transfer activity be estimated on a provincial basis.

5 Energy Expended for Waste Disposal Processing

There is an energy component input at landfill sites which is related to the management of the site, the internal movement, compaction and covering of waste, and the issues related to closure or opening of cells. There is also a requirement to move waste, which is delivered in small loads, to containers or specified areas on site to be consolidated later and moved to the working face of the landfill.

Based on the assessment of the Vancouver Landfill, energy input to landfill operations has been estimated at 10.5 MJ per tonne of waste disposed. The estimated rate for CO_2 emissions is 0.7 kg/tonne of waste disposed. Tables C-9 and C-10 provide estimates developed by applying these emission factors to national waste estimates.

6 Processing Recyclables

This section discusses the energy and greenhouse gas emissions associated with the processes involved in preparing waste for recycling—that is after its collection but before final shipment to companies that will use the waste to replace virgin raw materials in their manufacturing processes. The activities are related to separation, grading, preparation and packaging for shipment. Work completed by the Tellus Institute has evaluated the cost impact of three

Table C-9 Energy inputs to waste landfill processing

Waste Source	Landfill Quantity (million tonnes)	Energy Input (gigajoules)	CO_2 Emissions (kilotonnes)
Residential	8.72	91,600	6.1
IC&I	8.81	92,400	6.1
C&D	4.54	47,690	3.2
Total	**22.48**	**236,000**	**15.4**

Table C-10 Energy input and carbon dioxide emissions for landfill processing in Canada, 1992

	Energy Inputs to Landfill Processing				**Total**
Waste	**Tonnes Generated ($x10^6$)**	**Tonnes Combusted ($x10^6$)**	**Tonnes Composted ($x10^6$)**	**Tonnes Recycled ($x10^6$)**	**Tonnes Landfilled ($x10^6$)**
Waste Source					
Residential	10.54	0.64	0.32	0.87	8.72
IC&I	12.66	0.22	0.10	3.54	8.80
C&D	9.98	0.00	0.00	5.43	4.54
Total	**33.18**	**0.86**	**0.41**	**9.84**	**22.06**
Processing Energy Input Rates	**Generated (MJ/tonne)**	**Combusted (MJ/tonne)**	**Composted (MJ/tonne)**	**Recycled (MJ/tonne)**	**Landfilled (MJ/tonne)**
Rate per tonne					
Residential	N/A	0.0	0.0	0.0	10.5
IC&I	N/A	0.0	0.0	0.0	10.5
C&D	N/A	0.0	0.0	0.0	10.5
Processing Energy Inputs	**Generated (gigajoules)**	**Combusted (gigajoules)**	**Composted (gigajoules)**	**Recycled (gigajoules)**	**Landfilled (gigajoules)**
Energy	**Total Energy**				
Residential	91,550	0	0	0	91,550
IC&I	92,437	0	0	0	92,437
C&D	47,690	0	0	0	47,690
Total	**231,677**	**0**	**0**	**0**	**231,677**
Grand total in gigajoules					**231,677**
Processing CO_2 Emissions	**Generated (kilotonnes)**	**Combusted (kilotonnes)**	**Composted (kilotonnes)**	**Recycled (kilotonnes)**	**Landfilled (kilotonnes)**
Total Emissions	**Total CO_2**				
Residential	6	0	0	0	6
IC&I	6	0	0	0	6
C&D	3	0	0	0	3
Total	**15**	**0**	**0**	**0**	**15**
Total CO_2 Emissions in kilotonnes					**15**

different types of recyclable processing, and the energy aspects of these three systems are reviewed in table C-11. At this time, there are not many complex resource separation operations in Canada, and the energy component of recyclable materials is expected to be at the lower end of the estimates. Energy consumption was based on utility cost estimates. Electricity was assumed to be 90% of the utility budget, and an average industrial cost of 6.8 cents per kWh was used to convert utility cost to energy equivalents. The energy component for recyclables processing was calculated at 88 MJ per tonne for low input recycling to a higher end of 154 MJ per tonne for more energy intensive (mechanical) separation facilities. A figure of 100 MJ per tonne was used as a rough estimate of a Canadian average, and this rate was applied to all residential and IC&I recyclables (tables C-12 and C-13).

Energy input to composting varies depending on the process used. Outdoor and covered aerobic composting, which are presently being done in North America; will have energy requirements based on the blending and aeration required for process needs. Energy input to commercial composting would be expected to be 20 to 40 MJ per tonne of waste composted. Backyard composting will have no energy inputs as defined by this study.

Table C-11 Cost of and energy input to processing of recyclables (by type of facility)

Facility Type	Annual Capacity (tons tonnes)	$US Annual Utility Cost	$US Per tonne Utility Cost	Power Share	$Cdn Per tonne Power Cost/t	Rate KWH/t	Energy Input MJ per tonne
IPF	58,500						
Metric	59,436	$80,000	$1.35	90%	$1.66	24.40	87.85
RD	29,250						
Metric	29,718	$70,000	$2.36	90%	$2.90	42.71	153.74
SMF	23,400						
Metric	23,774	$55,000	$2.31	90%	$2.85	41.94	151.00

IPF—large volume, automated material separation

RD—recycling depot with manual separation, medium volume

SMF—small facility accepting multiple separated materials

Table C-12 Energy inputs to processing of recyclables (by type of waste)

Waste	Quantity Processed (million tonnes)	Energy Input (gigajoules)	Co_2 Emissions (kilotonnes)
Residential	1.19	97,000	6
IC&I	3.64	364,000	6
C&D	5.43	272,000	3
Total	**10.26**	**733,000**	**15**

Table C-13 Energy input and carbon dioxide emissions for recyclable processing in Canada, 1992

	Energy Inputs to Recycling Processing			Total	
Waste	**Tonnes Generated ($x10^6$)**	**Tonnes Combusted ($x10^6$)**	**Tonnes Composted ($x10^6$)**	**Tonnes Recycled ($x10^6$)**	**Tonnes Landfilled ($x10^6$)**
Waste Source					
Residential	10.54	0.64	0.32	0.87	8.72
IC&I	12.66	0.22	0.10	3.54	8.80
C&D	9.98	0.00	0.00	5.43	4.54
Total	**33.18**	**0.86**	**0.41**	**9.84**	**22.06**
Processing Energy Input Rates	**Generated (MJ/tonne)**	**Combusted (MJ/tonne)**	**Composted (MJ/tonne)**	**Recycled (MJ/tonne)**	**Landfilled (MJ/tonne)**
Rate per tonne					
Residential	N/A	0.0	33.5	100.0	0.0
IC&I	N/A	0.0	100.0	100.0	0.0
C&D	N/A	0.0	0.0	50.0	0.0
Processing Energy Inputs	**Generated (gigajoules)**	**Combusted (gigajoules)**	**Composted (gigajoules)**	**Recycled (gigajoules)**	**Landfilled (gigajoules)**
Energy	**Total Energy**				
Residential	97,220	0	10,422	86,798	0
IC&I	363,954	0	9,743	354,211	0
C&D	271,716	0	0	271,716	0
Total	**732,890**	**0**	**20,165**	**712,726**	**0**
Grand total in gigajoules					**732,890**
Processing CO_2 Emissions	**Generated (kilotonnes)**	**Combusted (kilotonnes)**	**Composted (kilotonnes)**	**Recycled (kilotonnes)**	**Landfilled (kilotonnes)**
Total Emissions	**Total CO_2**				
Residential	6.5	0	1.3	5.2	0
IC&I	6.2	0	0.2	6.0	0
C&D	3.0	0	0	3.0	0
Total	**15.6**	**0**	**1.4**	**14.2**	**0**
Total CO_2 Emissions in kilotonnes					**16**

7 Energy Input Rates

Figure C.1 illustrates the variation in energy inputs required to operate various activities in solid waste management systems. The rates are additive, in that a recycled waste would have a collection input as well as a processing input.

The figure illustrates that residential recycling activity has the highest energy input rate, at almost 500 MJ/tonne. Landfill has a low energy input requirement, at approximately 10 MJ/tonne.

8 National Energy Inputs and Carbon Dioxide Emissions for Solid Waste Management

In table C-14, the full impact of energy inputs and CO_2 emissions is summarized, and average rates are provided based on these totals and the mixed set of transportation and processing parameters that apply to each waste classification. The overall total of energy inputs is 6.6 petajoules (pJ), and the total CO_2 emissions is 665 kilotonnes of CO_2 equivalents. The subsets of the system are summarized in preceding tables as follows:

- Table C-4 summarizes energy and emissions for waste collection
- Table C-8 summarizes energy and emissions for waste transfer operations
- Table C-10 summarizes energy and emissions for landfill site operations
- Table C-13 summarizes energy and emissions for waste recycling processing and composting

Figure C.2 illustrates the application of these energy input rates to the quantities of waste managed in the Canadian system. 80% of the energy input goes to the collection of waste with an additional 6% to the transportation related to transfer stations.

9 Conclusions on Energy Usage for Solid Waste Management

Nationally, solid waste management accounts for a very small proportion of the energy used in Canada. In 1991, primary energy demand for Canada was 9,108 petajoules (Canada's National Report on Climate Change, 1994) and the total transportation sector demand was 1,742 petajoules. The waste management energy input represents only 0.07% of total national energy demand and 0.38% of transportation sector demand.

Energy requirements for waste management are expected to grow significantly as we move from the present level of diversion to the national targets, unless collection systems are modified to reduce energy consumption. The collection of recyclables uses about three times as much energy as the collection of garbage on a unit tonnage basis.

The collection of recyclables greatly increases energy consumption for waste management, but this energy consumption increase is significantly lower than the amount of energy saved by the introduction of recycled material into basic production processes as a substitute for virgin material. There are very large energy benefits to overall economic activity from diversion and recycling of steel, aluminum and paper with lower, yet also positive, contributions from plastic and glass. The benefits, unfortunately, do not accrue to the sector collecting the recyclable material but could be an important factor in meeting national energy reduction and greenhouse gas emission targets.

The largest energy source for waste management is refined petroleum products, dominated by the use of diesel as the fuel of choice for most of the waste collection and transportation activities.

To date, there is no indication that diversion of waste causes dramatic changes in the heating value of waste bound for combustion, but larger scale diversion may effect the heat content of

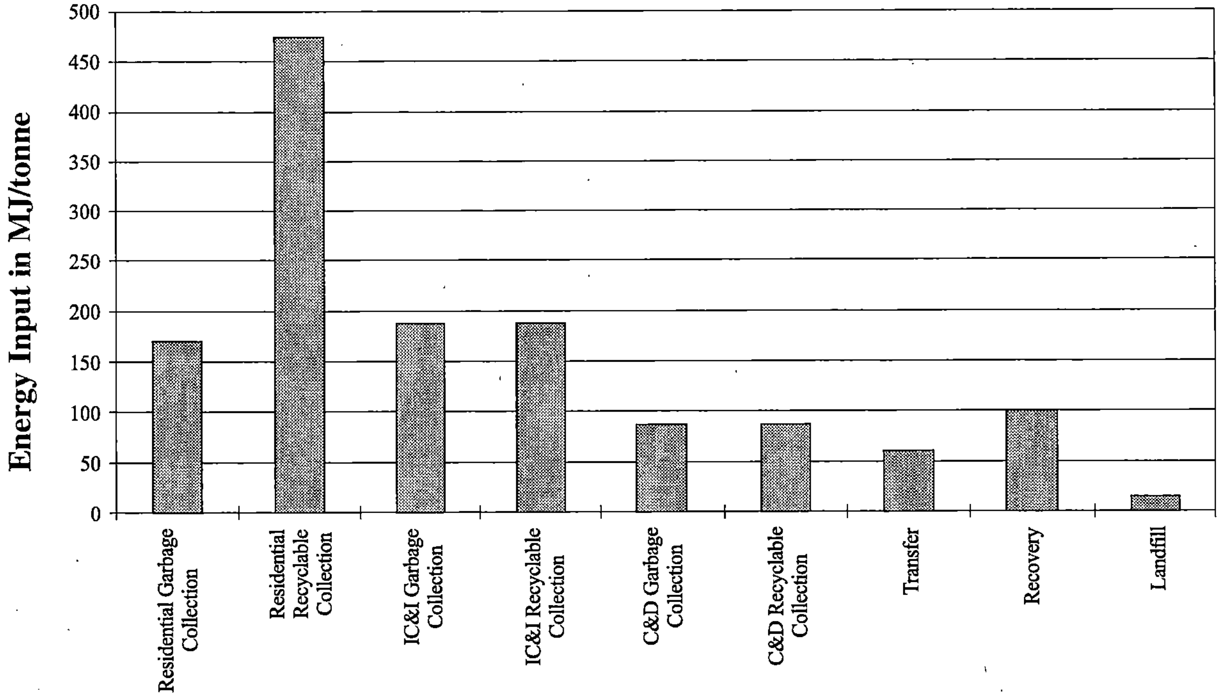

Figure C.1 Energy input rates for solid waste management activities

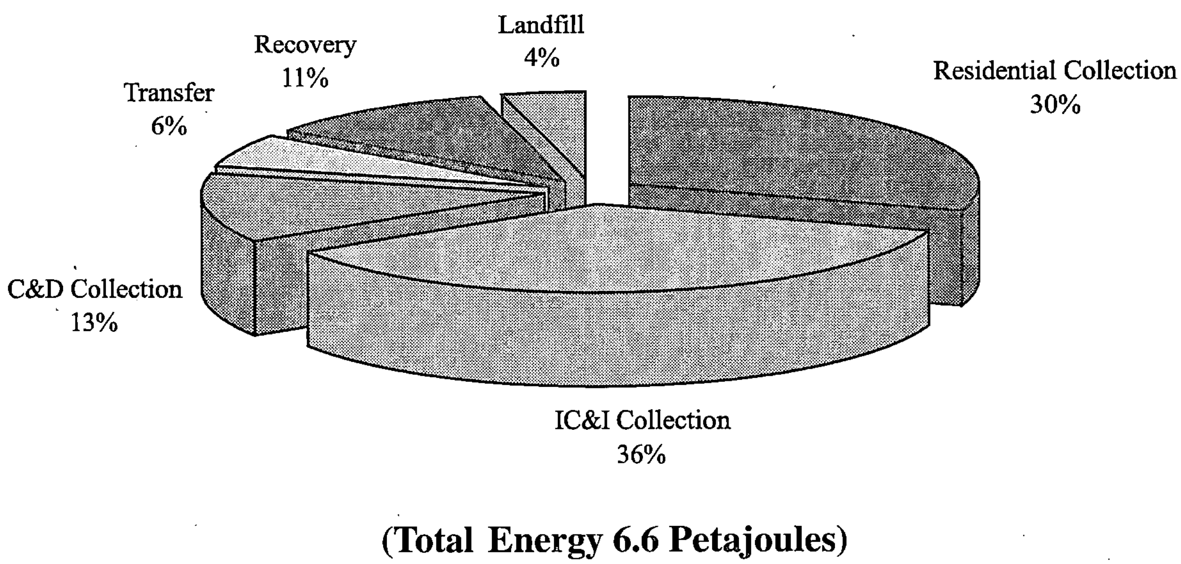

Figure C.2 Summary of annual energy inputs for solid waste management

Table C-14 Energy input and carbon dioxide emission for waste collection and processing in Canada, 1992

	Energy Inputs to Collection and Processing			Total	
Waste	**Tonnes Generated ($x10^6$)**	**Tonnes Combusted ($x10^6$)**	**Tonnes Composted ($x10^6$)**	**Tonnes Recycled ($x10^6$)**	**Tonnes Landfilled ($x10^6$)**
Waste Source					
Residential	10.54	0.64	0.32	0.87	8.72
IC&I	12.66	0.22	0.10	3.54	8.80
C&D	9.98	0.00	0.00	5.43	4.54
Total	**33.18**	**0.86**	**0.41**	**9.84**	**22.06**

Collection and Processing Energy Input Rates (AVG)	Generated (MJ/tonne)	Combusted (MJ/tonne)	Composted (MJ/tonne)	Recycled (MJ/tonne)	Landfilled (MJ/tonne)
Rate per tonne					
Residential	227.52	190.2	88.1	575.0	200.7
IC&I	238.59	209.2	286.0	286.0	219.7
C&D	116.02			134.0	94.5

Collection and Processing Energy Inputs	Generated (gigajoules)	Combusted (gigajoules)	Composted (gigajoules)	Recycled (gigajoules)	Landfilled (gigajoules)
Energy	**Total Energy**				
Residential	2,398,712	121,776	27,826	499,091	1,750,020
IC&I	3,020,401	45,257	27,866	1,013,044	1,934,234
C&D	1,157,413	0	0	728,199	429,214
Total	**6,576,526**	**167,033**	**55,691**	**2,240,333**	**4,113,468**
Grand total in gigajoules					**6,576,526**

Collection and Processing CO_2 Emissions	Generated (kilotonnes)	Combusted (kilotonnes)	Composted (kilotonnes)	Recycled (kilotonnes)	Landfilled (kilotonnes)
Total Emissions	**Total CO_2**				
Residential	170	9	5	34	122
IC&I	192	3	1	52	135
C&D	65	0	0	35	30
Total	**427**	**12**	**6**	**122**	**287**
Total CO_2 Emissions in kilotonnes					**427**

residual waste. As diversion increases there may be a need to look at the impacts on heating value.

An improved energy contribution can be made if the collection frequencies for garbage and recyclables can be altered by increasing the per household collection volumes per trip. This will be important for garbage collection; it is experiencing a trend towards higher energy use as higher quantities of recyclables are diverted, thus reducing the amount of garbage collection per stop. At the same time, the recyclable collection already has a high unit collection energy, and it would benefit from larger unit collection volumes by increasing collection efficiency. Improvements in this area will also have a positive impact on greenhouse gas emissions which are on an upward curve as recycling diversion increases.

Although the data used and the assumptions made to develop energy input estimates for the waste management sector are appropriate for the strategic level of this study, there is a need to collect more data and to develop some standardized data collection criteria for tracking future system changes and to provide a better basis for program evaluation. The collection of data will continue to be difficult due to the proprietary nature of much of the information sourced from the private sector operators. Provisions for data security and aggregation of reporting will be needed.

10 Energy Requirements in Production of Products from Waste Materials

The energy used in the production of goods that use waste material is usually done by blending recycled material into the production process with virgin raw material. Much of the energy consumed in the production of raw virgin material is not needed by substituting recycled material, representing an energy savings. table C-15 illustrates the energy savings for several commodities when virgin material is replaced with recycled material. The savings include energy used in raw material extraction, raw material processing and material manufacture. Transportation of raw and recycled materials is not included due to lack of available data (Tellus, 1992).

These energy estimates include one process back from each major stage in the manufacturing operation. For example, for metal production, the energy requirements for mining the raw materials and ores were determined but not those for producing the mining equipment. The energy used to produce additives was considered, but the energy requirements for the production of raw materials for each additive were not included.

Fibre waste streams consist of a wide range of paper products, including magazines. The paper products presented in table C-15 are considered representative of boxboard and corrugated cardboard but do not include fine paper products.

Energy requirements to produce several paper products using recycled paper are presented in table C-15. The energy required to make the three paper products from recycled material are similar (approximately 40,500 kjoules/kg). The use of recycled materials in the production of paper products causes a substantial reduction in energy requirements compared to using virgin materials—e.g., about a 50% reduction for producing unbleached coated boxboard.

Large reductions in production energy requirements are also apparent for recycled glass, steel and aluminum. Similar data were not readily available for other waste materials.

There are large potential energy savings which can be achieved through recycling of waste materials generated in Canada. It has been estimated that annual energy savings of 300 PJ per year could be accomplished by diverting materials from the waste stream into the production of goods, an amount that is roughly 50 times the energy input into waste management.

Table C-19 shows some of the energy savings that could be accomplished through recycling as well as the potential for energy recovery from different waste streams through combustion. In 1992, 64 PJ of energy was recovered from waste in Canada by using recycled material in place of virgin feedstock. This represents 21% of the potential that could be achieved if all of these waste streams were recycled (300 PJ). This energy saving came mainly from diversion of paper, glass, steel and aluminum. There were undoubtedly other savings achieved through recycling other materials such as the plastic streams but, to date, there is insufficient information to quantify these savings.

The following provides a further explanation of the energy parameters provided in table C-19. The table illustrates the potential in energy savings through reduction and reuse, recycling and capture of energy through EFW facilities.

Production Energy Virgin Material (Column 3)

- the energy required to manufacture the present volume of each specific waste stream currently (1992) abandoned as waste in Canada. For example, 14.25 PJ of energy is used to produced the magazines that are discarded as waste each year. This column represents the full energy saved if these products were not produced. Reduction and reuse activities have a direct linear effect in reducing total production energy requirements.

Maximum Energy Potential (Column 4)

- the energy invested in the production of the original material (column 3) plus the calorific value of the product. When waste materials are recycled into new production, the calorific value is maintained.

Maximum Energy Savings-Recycle (Column 5)

- the energy that would be saved in the production process by replacing virgin feedstock with recycled material from the waste stream. There are limitations on the recycling of many products based on the amount that can be blended into new production or the quality/characteristics of the end product.

Actual Diversion (% recycled) (Column 6)

- the present proportions of the specific waste streams that are diverted by recycling programs today in Canada. For example, 21% of other paper is presently recycled, saving 56 PJ of the potential energy savings of 226 PJ for this material.

Maximum Energy Recovered (Column 7)

- the calorific value in the waste streams that could be converted to energy through combustion and energy recovery facilities.

Actual Recovery (% incinerated) (Column 8)

- the present proportions of the specific waste streams that are converted to energy through EFW facilities in Canada. For example, 4% of the paper products go to combustion, recovering 5 PJ of the 134 PJ of calorific energy in the material.

11 Energy Content of Solid Waste

For any material, the energy content can be expressed as the heat of combustion, also known as its heating value. For fuels containing hydrogen, two heating values are usually reported: in the gross or higher heating value, where all water formed is condensed; and the net, or lower heating value, in which not all water is condensed out (Himmelblau 1974). For example, for lubrication oil, the higher heating value is 44,387 kjoules/kg while the lower heating value is 41,831 kjoules/kg. The lower heating value represents the actual heating value of the fuel, because some water vapour will remain in combustion systems, e.g., energy recovery boilers.

Table C-15 Production energy requirements for waste materials

Component	Virgin Material kjoules/kg	Recycled Material kjoules/kg	Examples
Bleached kraft paperboard	89,808		cartons for milk & frozen food, cosmetics, blister packs
Unbleached coated boxboard	71,321	40,483	cereal/cracker boxes, beverage carriers, dry soap containers
Linerboard	73,552	41,203	facing material of a corrugated cardboard container or in solid fibre boxes
Corrugating medium	55,274	40,111	middle, fluted layer in corrugated cardboard containers
Unbleached kraft paper paper	73,552		bags, shipping sacks, wrapping
Aluminum	241,688	9,668	
Glass	15,686	11,503	
Steel	22,774	19,637	
High-density polyethylene	21,108		containers for milk, juice and liquid detergents
Linear low-density polyethylene	83,034		film applications
Low-density polyethylene	98,267		film applications such as garment bags, bread wraps, produce bags, shrink wrap and stretch wrap; typical coating on inside of milk carton
Polypropylene	97,268		storage containers and some food packaging
Polyethylene terephthalate	122,691		beverage bottles and other food containers
Polystyrene	88,634		foamed products such as cups and trays; yogurt containers and clear plastic lids for take-out food containers
Polyvinyl chloride	84,021		many applications in construction and manufacturing; some used in bottles/rigid containers and film applications

Note: Energy values for fibres are based on bone-dry material.

The higher heating values of various waste components are presented in table C-16. Most values were obtained experimentally (Korzun 1990) when such values were not readily available. Estimates were calculated using an equation based on the elemental components of the waste (Khan, and Abu-Ghararah 1991). The data sources are identified in TC-16.

The heating values shown in table C-16 for plastics range from 21,108 to 47,245 kjoules/kg depending on the type of plastic considered. This wide range of heating values explains the variability of heating values listed for commingled plastic, since the energy available is strongly dependent on the type of plastic involved.

Table C-16 High heating values for waste materials

Component	High Heating Value kjoules/kg	Carbon Content (% by Weight)	Data Sources
Newsprint	19,707	49	E.A. Korzun (1990), Perry's (1984)
Corrugated cardboard	17,264	43	E.A. Korzun (1990)
Mixed paper	13,785—17,597	35—44	modified Dulong equation, estimate based on elemental analysis from Tellus (1992); carbon content value of 44 from Khan (1991); higher HHV from E.A. Korzun (1990)
Magazines	12,742	33	Perry's (1984)
Polyethylene	44,529—45,851	86	E.A. Korzun (1990); Perry's (1984) for low end
Polyvinyl chloride	22,735—26,558	38	high end based in vinyl scrap, Perry's (1984)
Polypropylene	47,245	88	modified Dulong equation, estimate for straight chain structure
Polystyrene	38,228	92	E.A. Korzun (1990)
Polyethylene	21,108	63	modified Dulong equation estimate for terephthalate straight chain structure
Polyurethane	26,112	63	Perry's (1984)
Commingled Plastic	18,252—33,432	45—60	modified Dulong equation used for low value, based on elemental analysis from Tellus (1992); E.A. Korzun (1990) for high heating value; carbon content value of 60% from Khan (1991)

cont'd next page

Table C-16 High heating values for waste materials (cont'd)

Component	High Heating Value kjoules/kg	Carbon Content (% by Weight)	Data Sources
Leaf and yard wste	16,428—20,611		ripe leaves and lawn grass, E.A. Korzun (1990)
Wood	15,338—20,016	43	modified Dulong equation used for low value, elemental analysis of wood from Tellus (1992); Perry's (1984) used for high value
Fats	38,296	73	Perry's (1984)
Food (mixed)	13,917	48	Perry's (1984)
Fruit	18,638	49	Perry's (1984)
Meat	28,970	60	Perry's (1984)
Food	18,691	48	modified Dulong equation, estimate based on food composition in Khan (1991)
Brush, grass, food waste, miscellaneous organics	7,671	19	modified Dulong equation; estimate based on elemental analysis from Tellus (1992)
Rubber - tires	32,316		E.A. Korzun (1990)
Commingled/other rubber	17,195—25,554	38	modified Dulong equation for low value, based on elemental analysis from Tellus (1992); Perry's (1984) for high value
Leather (mixed)	25,638	60	Perry's (1984)
Used lube oil	44,387	87	based on petroleum specific gravity = 0.90, Kirk Othmer (1985); Himmelblau (1974) for calorific value; carbon content based on No. 4 fuel oil
Other/commingled textiles	17,620	46	modified Dulong equation estimate based on elemental analysis from Tellus (1992); high end from Perry's

Many components of solid waste have no residual energy content. Despite the large amounts of energy used in the production of virgin steel, aluminum and glass (ranging from 22,774 to 241,688 kjoules/kg), these materials have effectively no heating value as fuels.

Typical carbon content of waste components is also provided in table C-16. High carbon content generally means that the material has a high energy content. This is illustrated by plastics and used lube oil with high heating values on the order of 45,000 kjoules/kg. These materials have a carbon content over 85% by weight. Other materials with lower carbon contents (e.g., lower commingled textiles with 46% carbon) have lower high heating values (e.g., 17,620 kjoules/kg). Steel, aluminum and glass have very low carbon contents, which accounts for their poor heating values as fuels. Carbon content can also be used as a measure for potential greenhouse gas emissions for a material; that is, it represents maximum carbon dioxide emissions (assuming all carbon is fully oxidized). Actual carbon dioxide emissions depend on a number of factors including degree of char formation and pyrolysis conditions.

The energy content of mixed solid waste depends on the following factors (Hasselriis 1985):

- the energy available from the combustibles streams of solid waste including paper, cardboard, plastics, rubber, textiles, food, yard waste and wood;
- moisture content, which must be evaporated and takes energy away from heating value of fuel;

Table C-17 Heating values of wet and dry municipal solid waste

Component	Wet MSW Heating Value (kjoules/kg)	Dry MSW Heating Value (kjoules/kg)
As-received MSW	10,458	14,641
Paper, mixed	15,803	17,597
Newsprint	18,531	19,707
Corrugated cardboard	16,367	17,264
Mixed plastic	32,767	33,432
Polyethylene	43,427	45,851
Polystyrene	38,156	38,228
Tires	32,070	32,316
Leaves, 50% moisture	8,215	16,428
Leaves, 9.97% moisture	18,554	20,611
Lawn grass, 65% moisture	6,251	17,878
Green logs	4,885	9,772
Demolition waste, softwood	16,965	18,396

Source: Korzun 1990

- inert materials such as glass, steel, aluminum, ceramics, dirt and sand (as well as non-combustible fillers in paper and plastics) which lower the heating value.

The presence of inert materials actually decreases the performance of combustibles available in solid waste since they act as heat sinks (i.e., they absorb heat) thus detracting from heat recovery.

The heating values is provided in table C-17 illustrate the effects of moisture content in mixed solid waste. A comparison is made among a variety of wet and dry refuse streams. For example, typical heating values for wet and dry (as-received) mixed solid waste are 10,458 and 14,651 kjoules/kg, respectively. The wet mixed waste has a lower heating value than the dry mixed waste.

12 Recoverable Energy Content of Waste Disposed of in Canada

Any combustible or flammable material has an energy content that can be recovered. The energy content is an intrinsic property of a material and is a function of the type of waste and the moisture content. Some solid wastes have more energy content than others, as illustrated in table C-16. In order to estimate the potentially recoverable energy content of waste disposed of in Canada, a distinction was made between those

Table C-18 Estimated recoverable energy content of discarded waste stream

Material	Energy Content of Landfilled Waste (TJ)	Energy Content of Incinerated Waste (in facilities without energy recovery) (TJ)	Total Energy Content of Discarded Waste (TJ)
Paper			
newsprint	21,267	201	21,468
magazines	210	4	213
cardboard	15,939	81	16,021
mixed paper	67,164	348	67,512
Plastic			
HDPE	3,557	19	3,575
LDPE	1	<1	1
PET	362	2	365
PVC	–	–	–
PS	–	–	–
PP	–	–	–
mixed plastics	38,593	226	38,815
Organics			
food waste	58,369	416	58,785
yard waste	26,745	174	26,919
mixed organics	2,031	9	2,040
Wood waste	29,658	68	29,727
Tires	746		746
Textiles	997	5	1,003
Total	**265,636**	**1,554**	**267,190**

materials with heating value and those materials without heating value. Consequently, those materials with heating values identified in table C-16 were used to estimate the energy content of waste disposed of in Canada; those materials not listed in the table (e.g. glass, aluminum, steel) are assumed to have minimal or negative energy values. A summary of energy contents of waste disposed of in Canada is presented in table C-18.

The energy content available in the wastes disposed of in landfills totals approximately 265,000 terajoules (TJ), and the energy content available in the wastes disposed of in incinerators with no energy recovery totals approximately 1,600 TJ.

Most (96%) of the waste disposed of in Canada in 1992 was sent to landfills which may or may not contain landfill gas recovery systems. As discussed in chapter 3, only 24 out of a reported 113 landfills throughout Canada have reported the installation of gas recovery systems. A smaller component (3-4%) of the waste was sent in 1992 to incinerators with or without energy generation capabilities. Most (approximately 91%) of the waste sent for incineration was burned in energy from waste facilities to extract the energy value in the waste and to convert it to a useful resource.

Most of the waste disposed of in Canada in 1992 was not recovered for its energy value, despite the potential energy available. Those wastes diverted through recycling programs have not been evaluated, since they are being put to use to reclaim their resource value of recyblables.

13 Energy Opportunities in Canada

Energy is used in the production of a product from virgin material. Energy is also required to recycle materials but, typically, there is less energy involved using recycled materials as feedstock. After their use in the marketplace, these materials can be reused, recycled, recovered (combusted) or landfilled. Some energy is used in these various stages but it is, in general, considerably lower than the production energy. The material has an energy potential (discussed earlier) consisting primarily of the production energy plus its energy content. The energy content of the material can be recovered when it is combusted.

Estimates are provided in the following sections for the maximum energy savings for each waste management method including reduction, reuse, recycling and recovery. Landfilling is also considered in the discussion. Areas for improvement in energy reduction are identified by looking at how each management method is presently being used in Canada.

14 Reduce and Reuse

Reduction and reuse activities lower the overall requirement for goods produced, with a corresponding linear reduction in the energy required to manufacture those goods. This is, in essence, a reduction in demand for new products as the item is no longer required by the consumer or is replaced with a previously used product. As illustrated in table C-19, there is a very high energy component for the initial production of products and materials, which can be directly reduced through reduction and reuse. The potential for energy savings through reduction and reuse is limited by the nature of many products, but there is large potential for waste volume and production energy reduction.

With the introduction of reuse activities, energy savings are accrued. Reused products linearly displace the virgin material used in production. Reused materials illustrate the benefits of the energy potential for the material (i.e., energy will not be expended again in production, and the product retains its intrinsic energy). High energy savings are possible by using reused material for similar-grade products.

15 Recycle

Recycling of a waste material involves using it for another application. Substantial savings of

Table C-19 Energy opportunities for waste generated in Canada

Waste Class	Type of Waste	Production Energy Virgin Material (PJ/year)	Maximum Energy Potential (PJ/year)	Max. Energy Savings-Recycle (PJ/year)	Actual Diversion (% recycled)	Max. Energy Recovered (PJ/year)	Actual Recovery (% Incinerated)
Paper	Magazines	14.25	16.75	6.29	0%	2.5	2%
	Other paper	602.77	748.66	266.16	21%	131.02	4%
	Subtotal	617.02	765.41	272.45	21%	133.52	4%
Glass		15.22	15.22	4.06	24%	NG	NG
Metals	Aluminum	15.95	15.95	15.31	6%	NG	NG
	Steel	64.4	64.4	8.87	57%	NG	NG
	Other Metals	ND	ND	ND	66%	NG	NG
	Subtotal	80.36	80.36	ND	59%	NG	NG
Plastics	HDPE	15.82	23.66	ND	6%	NG	NG
	PS	1.06	1.52	ND	0%	0.46	0%
	PET	3.8	4.46	ND	13%	0.65	3%
	Other plastic	49.63	66.01	ND	0%	16.06	0%
	Commingled plastic	106.75	141.98	ND	5%	34.54	7%
	Subtotal	177.06	237.63	ND	4%	59.13	5%
Organics	Leaf and yard	NA	36.93	ND	0%	33.25	4%
	Wood	ND	43.9	ND	18%	33.87	2%
	Food	ND	47.86	ND	0%	14.36	6%
	Other	ND	5.07	ND	0%	5.07	4%
	Subtotal	ND	133.76	ND	10%	86.55	4%
Inorganic		ND	ND	ND	ND	NG	NG
Other	Tires	ND	1.55	ND	81%	1.54	0%
	Textiles	ND	1.06	ND	43%	1.06	5%
	Other	ND	52.3	ND	1%	52.3	6%
	Subtotal	ND	54.91	ND	4%	54.9	6%
Total		**889.64**	**1,287.28**	**300.7**	**31%**	**334.1**	**3%**

Code Definitions:
ND = no data available
NG = negligible
NA = not applicable

energy are possible if less energy is required in the production of a product using recycled material as a feedstock. The maximum energy savings can be calculated as the difference in production energy between virgin and recycled material times the total waste generation rate. The difference in production energy can be interpreted as an energy credit, because virgin material is not required in the production of the product. If all the waste generated in Canada were recycled, the energy credit would represent the maximum energy savings using recycling as a waste management strategy.

The maximum possible energy savings using recycling are presented in table C-19 for some waste streams for which data were available. These energy savings estimates were developed using the energy credit in production energy (the difference between using virgin and recycled material) and the waste generation rates for the respective waste streams. The total energy savings for paper, glass, aluminum and other metals are 272, 4, 15.3 and 9 PJ/annum, respectively. These estimates represent the maximum savings using recycling as a waste management strategy (and assuming all waste is recycled). Recycling aluminum is the largest possible area for energy reduction (the maximum energy reduction is 96%). The lowest energy savings are from recycling steel (since production energy requirements using virgin or recycled metals are similar). High energy savings are expected for recycling plastics, but this is not substantiated by actual estimation, due to lack of recycling production energy data.

Recycling is an area where further improvement can be made in energy reduction. The total energy available for saving by recycling paper, glass and metals alone in Canada is about 300 PJ/year. Canada is presently recycling about 31% of the waste generated. Any modest increases in the use of recycled material as feedstock for production yields significant energy reductions.

16 Recovery

Energy cannot be recovered from some streams, and the only opportunity for energy reductions or savings is by reusing or recycling. These streams included glass, metals, concrete, gypsum and other inorganic wastes.

Any combustible or flammable material has an intrinsic energy content that is available for recovery at any time during its life cycle. Detailed recoverable energy estimates for each applicable waste material are provided in table C-19. The maximum recoverable energy content for each material was estimated by multiplying the total generated in 1992 by the heating value of the material. The maximum recoverable energy content of the waste generated in Canada is about 334 PJ/year. Paper is the largest source of recoverable energy.

Other waste streams such as food or wood have low production energy requirements but do have a significant potential for energy recovery. The maximum recoverable energy for these waste streams is about 87 PJ/year.

Approximately 3-4% of the waste generated in Canada was combusted in 1992. Energy could be recovered by incinerating combustible waste, but consideration should be made for reducing, reusing or recycling. These strategies can yield greater energy savings if properly implemented.

17 Landfill

Waste material in a landfill can be considered as a future energy resource. Landfill gas recovery and waste mined from the landfill are opportunities for energy conservation. Waste which is mined can be recovered (incinerated), reused or recycled.

Some energy can be recovered due to emission of landfill gases (primarily methane). Based on information in a recent study (Hickling 1994), the energy potential for landfill gases in Canada is estimated as 59 PJ/year (in 1995). The projected energy recovered from landfill gases was about 23 PJ/year by 1995. Less than 5% of the projected energy recovery from landfill gases in 1992 is estimated to have been achieved.

Landfilling represents the less attractive option from an energy standpoint. Waste in a landfill has energy potential that can be used only when the waste is removed.

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Provincial Energy Estimates for Waste Collection

Table D-1 Energy inputs to waste collection, Northwest Territories

Waste	Tonnes Generated ($x10^3$)	Tonnes Combusted ($x10^3$)	Tonnes Composted ($x10^3$)	Tonnes Recycled ($x10^3$)	Tonnes Landfilled ($x10^3$)
Waste Source					
Residential	5.92	0.00	0.00	0.05	5.87
IC&I	12.02	0.00	0.00	2.21	9.81
C&D	31.17	0.00	0.00	11.56	19.61
Total	**49.11**	**0.00**	**0.00**	**13.82**	**35.29**

Collection Energy Input Rates	Generated (MJ/tonne)	Combusted (MJ/tonne)	Composted (MJ/tonne)	Recycled (MJ/tonne)	Landfilled (MJ/tonne)
Rate per tonne					
Residential	N/A	167.0	55.1	475.0	167.0
IC&I	N/A	186.0	186.0	186.0	186.0
C&D	N/A	0.0	0.0	84.0	84.0

Collection Energy Inputs	Generated (gigajoules)	Combusted (gigajoules)	Composted (gigajoules)	Recycled (gigajoules)	Landfilled (gigajoules)
Energy	**Total Energy**				
Residential	1,004	0	0	24	980
IC&I	2,236	0	0	411	1,825
C&D	2,618	0	0	971	1,647
Total	**5,858**	**0**	**0**	**1,406**	**4,452**
Grand total in gigajoules					**5,858**

Collection CO_2 Emissions	Generated (kilotonnes)	Combusted (kilotonnes)	Composted (kilotonnes)	Recycled (kilotonnes)	Landfilled (kilotonnes)
Total Emissions	**Total CO_2**				
Residential	0.1	-	-	0.0	0.1
IC&I	0.2	-	-	0.0	0.1
C&D	0.2	-	-	0.1	0.1
Total	**0.4**	**-**	**-**	**0.1**	**0.3**
Total CO_2 emissions in kilotonnes					**0**

Table D-2 Energy inputs to waste collection, Yukon

Waste	Tonnes Generated ($x10^3$)	Tonnes Combusted ($x10^3$)	Tonnes Composted ($x10^3$)	Tonnes Recycled ($x10^3$)	Tonnes Landfilled ($x10^3$)
Waste Source					
Residential	3.03	0.00	0.03	0.21	2.80
IC&I	6.13	0.00	0.03	1.31	4.80
C&D	15.24	0.00	0.00	5.65	9.59
Total	**24.40**	**0.00**	**0.05**	**7.18**	**17.18**

Collection Energy Input Rates	Generated (MJ/tonne)	Combusted (MJ/tonne)	Composted (MJ/tonne)	Recycled (MJ/tonne)	Landfilled (MJ/tonne)
Rate per tonne					
Residential	N/A	167.0	55.1	475.0	167.0
IC&I	N/A	186.0	186.0	186.0	186.0
C&D	N/A	0.0	0.0	84.0	84.0

Collection Energy Inputs	Generated (gigajoules)	Combusted (gigajoules)	Composted (gigajoules)	Recycled (gigajoules)	Landfilled (gigajoules)
Energy	**Total Energy**				
Residential	569	0	1	101	467
IC&I	1,140	0	5	244	892
C&D	1,280	0	0	475	805
Total	**2,990**	**0**	**6**	**820**	**2,164**
Grand total in gigajoules					**2,990**

Collection CO_2 Emissions	Generated (kilotonnes)	Combusted (kilotonnes)	Composted (kilotonnes)	Recycled (kilotonnes)	Landfilled (kilotonnes)
Total Emissions	Total CO_2				
Residential	0.0	-	0.0	0.0	0.0
IC&I	0.1	-	0.0	0.0	0.1
C&D	0.1	-	-	0.0	0.1
Total	**0.2**	**-**	**0.0**	**0.1**	**0.2**
Total CO_2 emissions in kilotonnes					**0**

Table D-3 Energy inputs to waste collection, British Columbia

Waste	Tonnes Generated ($x10^3$)	Tonnes Combusted ($x10^3$)	Tonnes Composted ($x10^3$)	Tonnes Recycled ($x10^3$)	Tonnes Landfilled ($x10^3$)
Waste Source					
Residential	1,267.58	122.10	41.40	100.80	1,003.29
IC&I	1,440.07	76.15	0.00	411.84	952.08
C&D	1,317.82	0.00	0.00	508.19	809.63
Total	**4,025.47**	**198.25**	**41.40**	**1,020.82**	**2,765.00**

Collection Energy Input Rates	Generated (MJ/tonne)	Combusted (MJ/tonne)	Composted (MJ/tonne)	Recycled (MJ/tonne)	Landfilled (MJ/tonne)
Rate per tonne					
Residential	N/A	167.0	55.1	475.0	167.0
IC&I	N/A	186.0	186.0	186.0	186.0
C&D	N/A	0.0	0.0	84.0	84.0

Collection Energy Inputs	Generated (gigajoules)	Combusted (gigajoules)	Composted (gigajoules)	Recycled (gigajoules)	Landfilled (gigajoules)
Energy	**Total Energy**				
Residential	238,100	20,390	2,281	47,879	167,549
IC&I	267,853	14,164	0	76,601	177,087
C&D	110,697	0	0	42,688	68,009
Total	**616,649**	**34,555**	**2,281**	**167,168**	**412,645**
Grand total in gigajoules					**616,649**

Collection CO_2 Emissions	Generated (kilotonnes)	Combusted (kilotonnes)	Composted (kilotonnes)	Recycled (kilotonnes)	Landfilled (kilotonnes)
Total Emissions	**Total CO_2**				
Residential	17.1	1.4	0.5	3.4	11.8
IC&I	18.9	1.0	-	5.4	12.5
C&D	7.8	-	-	3.0	4.8
Total	**43.9**	**2.4**	**0.5**	**11.8**	**29.2**
Total CO_2 emissions in kilotonnes					**44**

Table D-4 Energy inputs to waste collection, Alberta

Waste	Tonnes Generated ($x10^3$)	Tonnes Combusted ($x10^3$)	Tonnes Composted ($x10^3$)	Tonnes Recycled ($x10^3$)	Tonnes Landfilled ($x10^3$)
Waste Source					
Residential	654.27	0.00	16.01	17.60	620.66
IC&I	1,474.13	0.00	0.71	150.63	1,322.79
C&D	917.29	0.00	0.00	378.10	539.19
Total	**3,045.68**	**0.00**	**16.72**	**546.33**	**2,482.63**

Collection Energy Input Rates	Generated (MJ/tonne)	Combusted (MJ/tonne)	Composted (MJ/tonne)	Recycled (MJ/tonne)	Landfilled (MJ/tonne)
Rate per tonne					
Residential	N/A	167.0	55.1	475.0	167.0
IC&I	N/A	186.0	186.0	186.0	186.0
C&D	N/A	0.0	0.0	84.0	84.0

Collection Energy Inputs	Generated (gigajoules)	Combusted (gigajoules)	Composted (gigajoules)	Recycled (gigajoules)	Landfilled (gigajoules)
Energy	**Total Energy**				
Residential	112,891	0	882	8,359	103,650
IC&I	274,187	0	131	28,017	246,039
C&D	77,052	0	0	31,761	45,292
Total	**464,130**	**0**	**1,014**	**68,136**	**394,980**
Grand total in gigajoules					**464,130**

Collection CO_2 Emissions	Generated (kilotonnes)	Combusted (kilotonnes)	Composted (kilotonnes)	Recycled (kilotonnes)	Landfilled (kilotonnes)
Total Emissions	**Total CO_2**				
Residential	8.1	-	0.2	0.6	7.3
IC&I	19.4	-	0.0	2.0	17.4
C&D	5.4	-	-	2.2	3.2
Total	**32.9**	**-**	**0.2**	**4.8**	**27.9**
Total CO_2 emissions in kilotonnes					**32.9**

Table D-5 Energy inputs to waste collection, Saskatchewan

Waste	Tonnes Generated ($x10^3$)	Tonnes Combusted ($x10^3$)	Tonnes Composted ($x10^3$)	Tonnes Recycled ($x10^3$)	Tonnes Landfilled ($x10^3$)
Waste Source					
Residential	437.92	0.00	0.10	21.40	416.43
IC&I	461.87	0.00	0.00	79.03	382.84
C&D	360.42	0.00	0.00	85.78	274.64
Total	**1,260.21**	**0.00**	**0.10**	**186.21**	**1,073.90**

Collection Energy Input Rates	Generated (MJ/tonne)	Combusted (MJ/tonne)	Composted (MJ/tonne)	Recycled (MJ/tonne)	Landfilled (MJ/tonne)
Rate per tonne					
Residential	N/A	167.0	55.1	475.0	167.0
IC&I	N/A	186.0	186.0	186.0	186.0
C&D	N/A	0.0	0.0	84.0	84.0

Collection Energy Inputs	Generated (gigajoules)	Combusted (gigajoules)	Composted (gigajoules)	Recycled (gigajoules)	Landfilled (gigajoules)
Energy	**Total Energy**				
Residential	79,713	0	5	10,165	69,544
IC&I	85,908	0	0	14,700	71,208
C&D	30,275	0	0	7,205	23,070
Total	**195,897**	**0**	**5**	**32,070**	**163,821**
Grand total in gigajoules					**195,897**

Collection CO_2 Emissions	Generated (kilotonnes)	Combusted (kilotonnes)	Composted (kilotonnes)	Recycled (kilotonnes)	Landfilled (kilotonnes)
Total Emissions	**Total CO_2**				
Residential	5.6	-	0.0	0.7	4.9
IC&I	6.1	-	0.0	1.0	5.0
C&D	2.1	-	-	0.5	1.6
Total	**13.8**	**-**	**0.0**	**2.3**	**11.6**
Total CO_2 emissions in kilotonnes					**14**

Table D-6 Energy inputs to waste collection, Manitoba

Waste	Tonnes Generated (x10³)	Tonnes Combusted (x10³)	Tonnes Composted (x10³)	Tonnes Recycled (x10³)	Tonnes Landfilled (x10³)
Waste Source					
Residential	464.76	0.00	1.41	3.51	459.84
IC&I	492.58	0.00	0.00	63.57	429.01
C&D	342.09	0.00	0.00	81.42	260.68
Total	**1,299.44**	**0.00**	**1.41**	**148.50**	**1,149.53**

Collection Energy Input Rates	Generated (MJ/tonne)	Combusted (MJ/tonne)	Composted (MJ/tonne)	Recycled (MJ/tonne)	Landfilled (MJ/tonne)
Rate per tonne					
Residential	N/A	167.0	55.1	475.0	167.0
IC&I	N/A	186.0	186.0	186.0	186.0
C&D	N/A	0.0	0.0	84.0	84.0

Collection Energy Inputs	Generated (gigajoules)	Combusted (gigajoules)	Composted (gigajoules)	Recycled (gigajoules)	Landfilled (gigajoules)
Energy	**Total Energy**				
Residential	78,540	0	78	1,669	76,793
IC&I	91,620	0	0	11,824	79,796
C&D	28,736	0	0	6,839	21,897
Total	**198,896**	**0**	**78**	**20,332**	**178,486**
Grand total in gigajoules					**198,896**

Collection CO_2 Emissions	Generated (kilotonnes)	Combusted (kilotonnes)	Composted (kilotonnes)	Recycled (kilotonnes)	Landfilled (kilotonnes)
Total Emissions	**Total CO_2**				
Residential	5.6	-	0.0	0.1	5.4
IC&I	6.5	-	-	0.8	5.6
C&D	2.0	-	-	0.5	1.5
Total	**14.1**	**-**	**0.0**	**1.4**	**12.6**
Total CO_2 emissions in kilotonnes					**14**

Table D-7 Energy inputs to waste collection, Ontario

Waste	Tonnes Generated ($x10^3$)	Tonnes Combusted ($x10^3$)	Tonnes Composted ($x10^3$)	Tonnes Recycled ($x10^3$)	Tonnes Landfilled ($x10^3$)
Waste Source					
Residential	4.33	0.15	0.23	0.48	3.48
IC&I	4.03	0.05	0.10	1.37	2.52
C&D	5.16	0.00	0.00	4.17	0.99
Total	**13.52**	**0.19**	**0.32**	**6.02**	**6.99**

Collection Energy Input Rates	Generated (MJ/tonne)	Combusted (MJ/tonne)	Composted (MJ/tonne)	Recycled (MJ/tonne)	Landfilled (MJ/tonne)
Rate per tonne					
Residential	N/A	167.0	55.1	475.0	167.0
IC&I	N/A	186.0	186.0	186.0	186.0
C&D	N/A	0.0	0.0	84.0	84.0

Collection Energy Inputs	Generated (gigajoules)	Combusted (gigajoules)	Composted (gigajoules)	Recycled (gigajoules)	Landfilled (gigajoules)
Energy	**Total Energy**				
Residential	845,657	24,474	12,460	227,473	581,250
IC&I	749,676	8,794	17,969	254,158	468,756
C&D	433,129	0	0	350,260	82,869
Total	**2,028,462**	**33,268**	**30,429**	**831,891**	**1,132,874**
Grand total in gigajoules					**2,028,462**

Collection CO_2 Emissions	Generated (kilotonnes)	Combusted (kilotonnes)	Composted (kilotonnes)	Recycled (kilotonnes)	Landfilled (kilotonnes)
Total Emissions	**Total CO_2**				
Residential	61.4	1.7	2.5	16.1	41.1
IC&I	52.9	0.6	1.3	17.9	33.1
C&D	30.6	-	-	24.8	5.9
Total	**145.0**	**2.4**	**3.8**	**58.8**	**80.0**
Total CO_2 emissions in kilotonnes					**145**

Table D-8 Energy inputs to waste collection, Quebec

Waste	Tonnes Generated (x10³)	Tonnes Combusted (x10³)	Tonnes Composted (x10³)	Tonnes Recycled (x10³)	Tonnes Landfilled (x10³)
Waste Source					
Residential	2.59	0.30	0.02	0.23	2.04
IC&I	3.84	0.08	0.00	1.35	2.41
C&D	1.60	0.00	0.00	0.17	1.43
Total	**8.03**	**0.38**	**0.02**	**1.75**	**5.88**

Collection Energy Input Rates	Generated (MJ/tonne)	Combusted (MJ/tonne)	Composted (MJ/tonne)	Recycled (MJ/tonne)	Landfilled (MJ/tonne)
Rate per tonne					
Residential	N/A	167.0	55.1	475.0	167.0
IC&I	N/A	186.0	186.0	186.0	186.0
C&D	N/A	0.0	0.0	84.0	84.0

Collection Energy Inputs	Generated (gigajoules)	Combusted (gigajoules)	Composted (gigajoules)	Recycled (gigajoules)	Landfilled (gigajoules)
Energy	**Total Energy**				
Residential	500,613	50,634	1,210	108,208	340,561
IC&I	713,442	14,099	0	251,136	448,207
C&D	134,399	0	0	14,551	119,848
Total	**1,348,454**	**64,733**	**1,210**	**373,895**	**908,616**
Grand total in gigajoules					**1,348,454**

Collection CO_2 Emissions	Generated (kilotonnes)	Combusted (kilotonnes)	Composted (kilotonnes)	Recycled (kilotonnes)	Landfilled (kilotonnes)
Total Emissions	**Total CO_2**				
Residential	35.5	3.6	0.2	7.7	24.1
IC&I	50.3	1.0	-	17.7	31.7
C&D	9.5	-	-	1.0	8.5
Total	**95.4**	**4.6**	**0.2**	**26.4**	**64.2**
Total CO_2 emissions in kilotonnes					**95**

Table D-9 Energy inputs to waste collection, New Brunswick

Waste	Tonnes Generated ($x10^3$)	Tonnes Combusted ($x10^3$)	Tonnes Composted ($x10^3$)	Tonnes Recycled ($x10^3$)	Tonnes Landfilled ($x10^3$)
Waste Source					
Residential	237.29	0.00	0.64	3.88	232.77
IC&I	221.13	0.00	0.00	30.91	190.22
C&D	139.90	0.00	0.00	6.93	132.97
Total	**598.33**	**0.00**	**0.64**	**41.72**	**555.96**

Collection Energy Input Rates	Generated (MJ/tonne)	Combusted (MJ/tonne)	Composted (MJ/tonne)	Recycled (MJ/tonne)	Landfilled (MJ/tonne)
Rate per tonne					
Residential	N/A	167.0	55.1	475.0	167.0
IC&I	N/A	186.0	186.0	186.0	186.0
C&D	N/A	0.0	0.0	84.0	84.0

Collection Energy Inputs	Generated (gigajoules)	Combusted (gigajoules)	Composted (gigajoules)	Recycled (gigajoules)	Landfilled (gigajoules)
Energy	**Total Energy**				
Residential	40,749	0	35	1,841	38,873
IC&I	41,131	0	0	5,750	35,381
C&D	11,752	0	0	582	11,169
Total	**93,632**	**0**	**35**	**8,173**	**85,423**
Grand total in gigajoules					**93,632**

Collection CO_2 Emissions	Generated (kilotonnes)	Combusted (kilotonnes)	Composted (kilotonnes)	Recycled (kilotonnes)	Landfilled (kilotonnes)
Total Emissions	**Total CO_2**				
Residential	2.9	-	0.0	0.1	2.7
IC&I	2.9	-	-	0.4	2.5
C&D	0.8	-	-	0.0	0.8
Total	**6.6**	**-**	**0.0**	**0.6**	**6.0**
Total CO_2 emissions in kilotonnes					**7**

Table D-10 Energy inputs to waste collection, Nova Scotia

Waste	Tonnes Generated ($x10^3$)	Tonnes Combusted ($x10^3$)	Tonnes Composted ($x10^3$)	Tonnes Recycled ($x10^3$)	Tonnes Landfilled ($x10^3$)
Waste Source					
Residential	345.75	31.76	7.03	9.07	297.88
IC&I	315.65	7.94	0.00	48.83	258.88
C&D	60.56	0.00	0.00	9.50	51.06
Total	**721.95**	**39.70**	**7.03**	**67.40**	**607.82**

Collection Energy Input Rates	Generated (MJ/tonne)	Combusted (MJ/tonne)	Composted (MJ/tonne)	Recycled (MJ/tonne)	Landfilled (MJ/tonne)
Rate per tonne					
Residential	N/A	167.0	55.1	475.0	167.0
IC&I	N/A	186.0	186.0	186.0	186.0
C&D	N/A	0.0	0.0	84.0	84.0

Collection Energy Inputs	Generated (gigajoules)	Combusted (gigajoules)	Composted (gigajoules)	Recycled (gigajoules)	Landfilled (gigajoules)
Energy	**Total Energy**				
Residential	59,748	5,304	388	4,310	49,746
IC&I	58,710	1,477	0	9,082	48,151
C&D	5,087	0	0	798	4,289
Total	**123,545**	**6,781**	**388**	**14,190**	**102,186**
Grand total in gigajoules					**123,545**

Collection CO_2 Emissions	Generated (kilotonnes)	Combusted (kilotonnes)	Composted (kilotonnes)	Recycled (kilotonnes)	Landfilled (kilotonnes)
Total Emissions	**Total CO_2**				
Residential	4.3	0.4	0.1	0.3	3.5
IC&I	4.1	0.1	-	0.6	3.4
C&D	0.4	-	-	0.1	0.3
Total	**8.8**	**0.5**	**0.1**	**1.0**	**7.2**
Total CO_2 emissions in kilotonnes					**9**

Table D-11 Energy inputs to waste collection, Prince Edward Island

Waste	Tonnes Generated ($x10^3$)	Tonnes Combusted ($x10^3$)	Tonnes Composted ($x10^3$)	Tonnes Recycled ($x10^3$)	Tonnes Landfilled ($x10^3$)
Waste Source					
Residential	35.23	16.72	0.34	1.90	16.29
IC&I	68.49	4.18	0.00	11.49	52.82
C&D	5.95	0.00	0.00	0.24	5.71
Total	**109.67**	**20.89**	**0.34**	**13.62**	**74.82**

Collection Energy Input Rates	Generated (MJ/tonne)	Combusted (MJ/tonne)	Composted (MJ/tonne)	Recycled (MJ/tonne)	Landfilled (MJ/tonne)
Rate per tonne					
Residential	N/A	167.0	55.1	475.0	167.0
IC&I	N/A	186.0	186.0	186.0	186.0
C&D	N/A	0.0	0.0	84.0	84.0

Collection Energy Inputs	Generated (gigajoules)	Combusted (gigajoules)	Composted (gigajoules)	Recycled (gigajoules)	Landfilled (gigajoules)
Energy	**Total Energy**				
Residential	6,430	2,791	19	900	2,720
IC&I	12,739	777	0	2,137	9,825
C&D	500	0	0	20	480
Total	**19,669**	**3,569**	**19**	**3,057**	**13,024**
Grand total in gigajoules					**19,669**

Collection CO_2 Emissions	Generated (kilotonnes)	Combusted (kilotonnes)	Composted (kilotonnes)	Recycled (kilotonnes)	Landfilled (kilotonnes)
Total Emissions	**Total CO_2**				
Residential	0.5	0.2	0.0	0.1	0.2
IC&I	0.9	0.1	-	0.2	0.7
C&D	0.0	-	-	0.0	0.0
Total	**1.4**	**0.3**	**0.0**	**0.2**	**0.9**
Total CO_2 emissions in kilotonnes					**1**

Table D-12 Energy inputs to waste collection, Newfoundland

Waste	Tonnes Generated ($x10^3$)	Tonnes Combusted ($x10^3$)	Tonnes Composted ($x10^3$)	Tonnes Recycled ($x10^3$)	Tonnes Landfilled ($x10^3$)
Waste Source					
Residential	166.98	19.89	0.80	2.87	143.42
IC&I	301.07	4.97	0.09	25.66	270.35
C&D	29.54	0.00	0.00	3.96	25.58
Total	**497.59**	**24.86**	**0.89**	**32.49**	**439.35**

Collection Energy Input Rates	Generated (MJ/tonne)	Combusted (MJ/tonne)	Composted (MJ/tonne)	Recycled (MJ/tonne)	Landfilled (MJ/tonne)
Rate per tonne					
Residential	N/A	167.0	55.1	475.0	167.0
IC&I	N/A	186.0	186.0	186.0	186.0
C&D	N/A	0.0	0.0	84.0	84.0

Collection Energy Inputs	Generated (gigajoules)	Combusted (gigajoules)	Composted (gigajoules)	Recycled (gigajoules)	Landfilled (gigajoules)
Energy	**Total Energy**				
Residential	28,681	3,321	44	1,364	23,951
IC&I	55,999	925	17	4,772	50,285
C&D	2,482	0	0	333	2,149
Total	**87,161**	**4,246**	**62**	**6,469**	**76,384**
Grand total in gigajoules					**87,161**

Collection CO_2 Emissions	Generated (kilotonnes)	Combusted (kilotonnes)	Composted (kilotonnes)	Recycled (kilotonnes)	Landfilled (kilotonnes)
Total Emissions	**Total CO_2**				
Residential	2.0	0.2	0.0	0.1	1.7
IC&I	4.0	0.1	0.0	0.3	3.6
C&D	0.2	-	-	0.0	0.2
Total	**6.2**	**0.3**	**0.0**	**0.5**	**5.4**
Total CO_2 emissions in kilotonnes					**6**

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