Development of Construction and Demolition Waste Recycling in Ontario

School of Engineering Practice SEP 704

Submitted to Dr. Brian Baetz
Submitted by Tomo Saotome
August, 2007

Abstract

Due to increasing waste volumes and a shortage of landfills, waste management is becoming a more significant subject of interest in Ontario. Construction and demolition (C&D) waste is one waste sub-category where the waste diversion rate has been low and there is room for improvement in the recycling of related materials. This inquiry, with particular emphasis on gypsum board, explored the existing waste management system in Ontario and examined the barriers to closing the recycling loop and development of markets for recycled materials. Through the research, the role of the government in creating a regulatory framework for gypsum recycling was examined using the Japanese recycling system as a model for comparison.

The C&D recycling loop consists of the three main phases of collection, recycling, and marketing. This work has analyzed the related regulatory framework and has determined the ineffectiveness of the existing 3Rs Regulations and low landfill tipping fees are the critical barriers for gypsum board recycling in Ontario. Detailed modification of existing 3Rs Regulations to achieve mandatory reporting, expansion of applicable projects, landfill taxes, and education of industry players are all recommended.

Table of Contents

Table of Figures and Tables

Figures

Tables

1. Introduction

The Government of Ontario has set a goal to divert 60 per cent of Ontario's waste by the end of 2008 through the 3R's (Reduce, Reuse, and Recycle), to reduce the impact on natural resources from waste disposal and to reduce the utilization of landfills in Ontario. Ontario generated more than 12 million tonnes of solid waste in 2002, of which 1.2 million tones were generated from the construction and demolition (C&D) sector (Ministry of Industry Canada, 2004). Only 12 per cent of this waste generated from the C&D sector was recycled (RIS International Ltd, 2005).

Japan also has waste issues because of its limited spaces for landfill sites and has implemented new C&D waste recycling regulations in 2000 to mitigate this problem. Today, Japan has started to increase the waste diversion of certain materials. The central issues of C&D waste recycling are becoming clear, such as materials that are difficult to recycle and a lack of connection between industrial demand and the recycling market.

Today, even though both the provincial government and its residents have identified the waste problem in Ontario and the importance of minimizing the use of natural resources, the low diversion rate for C&D wastes illustrates the difficulties in implementing a successful waste diversion program. This has led the author to reflect on how the C&D waste recycling process is structured and brought forth the central question of this inquiry: **"What are the barriers to stimulating markets for recycled C&D waste materials?"** Because of the structure of the recycling loop that consists of collection, remanufacturing and purchasing, it is important to establish a system that recycles materials that are purchased, as well as accomplishing a high collection rate of discarded materials.

The goal of this study was to review the existing waste management system in Ontario and explore the factors that will help close the recycling loop, using the Japanese recycling system as a model for comparison. The role of the government

in creating a regulatory framework for the enforcement of recycling, encouraging profitability of the recycling market and the development of recycling technology will be examined. The market for recycled materials is from the private sector, but the public sector needs to put in place incentives for the private sector to participate in the market.

Some questions naturally followed from the central research question that could deepen the inspection of each step in the recycling loop, with specific attention to gypsum board for which recovery rates are comparatively low. These guiding questions were;

1. Is there enough enforcement of C&D waste recycling?
2. Has an effective collection system for C&D waste been built?
3. What are the technological difficulties for recycling and is it possible to solve them?
4. Do consumers have the motivation to purchase recycled materials?

Figure 1.1 shows the structure of C&D recycling, focusing on the 3 phases of the recycling loop.

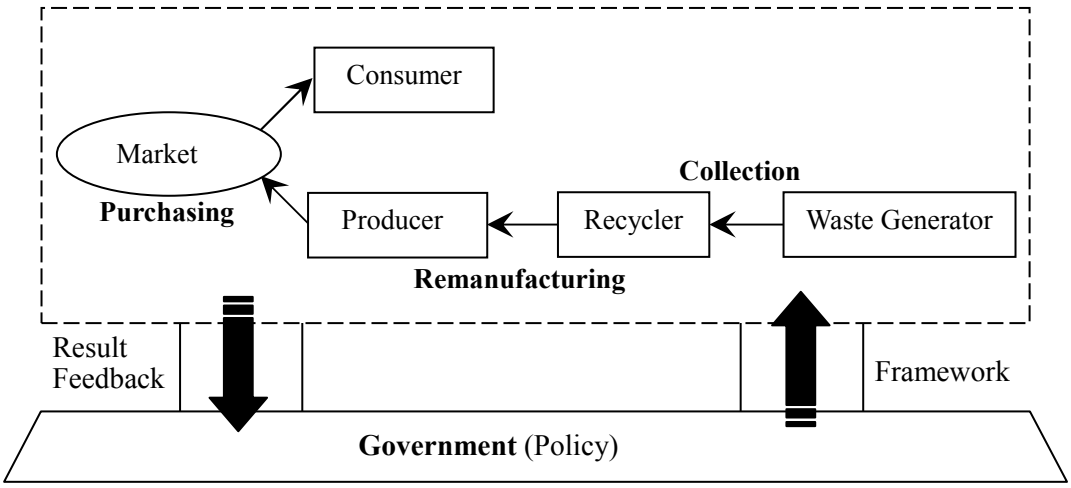


Figure1.1 The structure of C&D recycling

2. Background

2.1 The waste situation in Ontario

The volume of C&D waste is not as large as in other sectors. While 1.2 million tonnes of C&D waste were generated in 2002, the residential sector generated 4.4 million tonnes, and the industrial, commercial, and institutional (IC&I) sectors generated 6.5 million tonnes. However, the C&D recycling rate is the lowest of the three sectors (Ministry of Industry Canada, 2004). C&D wastes consist mainly of concrete, asphalt, metals, wood, and gypsum. These materials are currently being recovered and processed into recycled content products (Recycling Council of Ontario, 2005). Concrete and asphalt, in particular, are highly reused, but others are not recycled effectively. Even the recycling rate of concrete and asphalt are not high, compared to the Japanese recycling rates which are more than 98 percent[1] (Ministry of Land, Infrastructure and Transport Japan, 2006). The differences in the recycling rates can be explained by the difficulties of the recycling process and the demand for recycled materials from industry.

2.2 Definition of C&D waste

In this inquiry, Construction and Demolition (C&D) waste was defined as below.

> *Waste materials from the construction and demolition of roads, bridges and buildings such as wood, gypsum and metal*
>
> (Ministry of Industry Canada, 2004).

1. *Recycling* includes *Reuse* in Japan with the notion that both actions contain reusing a product after the end of life cycle.

2.3 Regulations for C&D waste

Ontario has 3Rs Regulations under the Environmental Protection Act. Ontario Regulation 102/94 and 103/94 are applied to building projects and strongly relate to C&D waste management. Mentioned below are two regulations for C&D waste management from projects that generate these wastes:

Ontario Regulation 102/94

This regulation applies for construction and demolition projects where the total floor area is at least 2,000 square metres. It requires owners to conduct a waste audit, and develop and implement waste reduction plans, and update them annually.

Ontario Regulation 103/94

This regulation applies for the construction and demolition projects where the total floor area is at least 2,000 square metres. It requires owners to have source separation and to ensure that the wastes are recycled. Materials to be recycled are indicated below.

Construction: Cardboard, Brick and Concrete, Drywall (unpainted), Steel, Wood (untreated)

Demolition: Brick and Concrete, Drywall (unpainted), Steel, Wood (untreated)

Table 2.1 Material to be recycled by establishments designated under Ontario's 3Rs Regulations

Waste	Construction over 2000m^2	Demolition over 2000m^2
Cardboard	○	○
Brick & Concrete	○	○
Drywall (unpainted)*[1]	○	-
Steel	○	○
Wood (Untreated)	○	○

○ Required

*1 Drywall is same as gypsum board

These regulations were created to minimize the wastes and maximize the diversion with the 3Rs, but significant lack of enforcement is pointed out by several reports, such as one prepared by The Recycling Council of Ontario (2005). This also affects the implementation of waste diversion and business competition (Kelleher Environmental, 2005). Regulations have been made to govern recycling in private sectors that do not take initiatives for their own waste management. However, these regulations are not implemented effectively with review by a third party. Given this reality, benefits for the observance of the regulations or regulations that foster increased reliance on market forces for recycling are needed.

2.4 Methodology

There are three main phases including collection, manufacturing, and purchasing in C&D waste recycling. The regulatory frame work is related to these phases. Therefore, the investigation proceeded according to these topics of collection, manufacturing, purchasing and the regulatory framework. Before these topics were explored in greater depth, anticipated findings were developed based on the key references and the Japanese system of recycling was addressed.

2.5 Anticipated findings

In response to the central question of **"What are the barriers to stimulating markets for recycled C&D waste materials?"**, the following anticipated findings were developed:

(1) An effective collection system may not be in place at the construction and demolition sites;
- Depending on the sites, recycling facilities are not in a suitable location and the cost for transportation of the recyclable materials may be significant.

(2) During the recycling process, remanufacturing technology and the quality of recycled products may be the barriers to making C&D materials a commodity.
- The development of technology will be necessary to allow for the creation

of materials. However, not all of the materials will be appropriate or simple to recycle such as chemical substances on gypsum board that make it difficult to recycle.

- The quality of the recycled materials may concern consumers who purchase them.

(3) In the market for recycled materials, there may be fewer incentives for consumers to purchase them.

- The market for recycled materials may possibly not even exist.
- There may be no benefit for the consumers to purchase the recycled products compared to virgin materials.
- Green purchasing may be promoted.

(4) The overall regulatory framework related for C&D waste management may not be strong enough.

- There may be a lack of enforcement of an auditing system established based on the 3Rs Regulations.
- Producers of the waste may not feel the responsibility to manage it.
- Benefits from the implementation of the 3Rs Regulations may not be indicated in the regulatory framework.

Several investigations have been done on the C&D waste situation in Ontario based on the analysis of the recycling market and the lack of enforcement of 3Rs Regulations such as *IC&I Sector Consultation Session To Discuss Options to Achieve 60% Diversion of Waste In Ontario* (Kelleher Environmental, 2005), *The Private Sector IC&I Waste Management System in Ontario* (RIS International Ltd., 2005), and *Regent Park Redevelopment Project Sustainable Community Design Appendix6: Demolition & Construction Waste* (Dillon Consulting Limited, 2004). On the other hand, the detailed barriers to the collection system and how a vigorous recycled material market can be established have not been well explored. The lack of attention to creating an effective recycled material market is the result of the 3Rs Regulations not being implemented properly, so difficulties have not been fully encountered yet. However, some difficulties can be predicted from the Japanese

experience before the new C&D regulations were made in 2000.

3. Investigation 1 : Collection and Recycling

The collection and recycling processes are closely linked because this connection affects the business opportunities which for the run by private companies. These companies are designed to professionally deal with this waste and the existing barriers depend on the materials. Therefore, this section examines the current collection system and recycling conditions of gypsum board in terms of the collection system and location of the recycling facility, technological difficulties in recycling, and secondary products demand.

3.1 Gypsum board overview

Gypsum is composed of calcium sulfate ($CaSO_4$) and water (H_2O). Gypsum board is also referred to as drywall or sheet rock. It is made by heating gypsum which is mined from deposits formed by ancient sea beds to remove the water. After that, it is covered with paper facing and backing. The advantages of gypsum board are fire resistance, sound resistance, and low cost. Considering these advantages, gypsum board is mainly used for interior walls and ceilings, as a base for metal tile, and even for exterior soffits. Because of this convenience, gypsum is widely used for residential housing. According to the *National Association of Home Builders Research Centre* in the U.S., the gypsum waste comprises 27 per cent of the total wastes from residential construction (Recycling Council of Ontario, 2005). It should be noted, however, that for a demolition project where the total floor area is under 2,000 square metres, unpainted gypsum board is not included in the materials to be recycled under Ontario Regulation 103/94.

Product size of gypsum board depends on manufacturers, but some standard sizes are available for most cases. Table 3.1 shows an example of sizes from *Lafarge North America*.

Table 3.1 Physical characteristics of Regular Drywall
(Lafarge North America, 2007)

Nominal thickness	1/4 in. (6.4mm)	3/8 in. (9.5mm)	1/2 in. (12.7mm)
Nominal width	4 ft.	4 ft.	4 ft. 54 in.
Standard length	8 ft.	8 ft. to 12 ft.	8 ft. to 16 ft.
Nominal weight	1.1 lbs/ft^2	1.3 lbs/ft^2	1.6 lbs/ft^2
	16.0 kg/sheet	18.9 kg/sheet	23.2 kg/sheet

3.2 Collection system and facility in Ontario

The flow of the wastes is shown in Figure 3.1. Wastes are collected in on-site bins, and a hauler brings it to landfills, recyclers, or a warehouse to store the wastes until it accumulates for a certain amount. Other than the recycling by the recyclers, gypsum board manufactures also collect the wastes from the construction sites and recycle them into new gypsum board production.

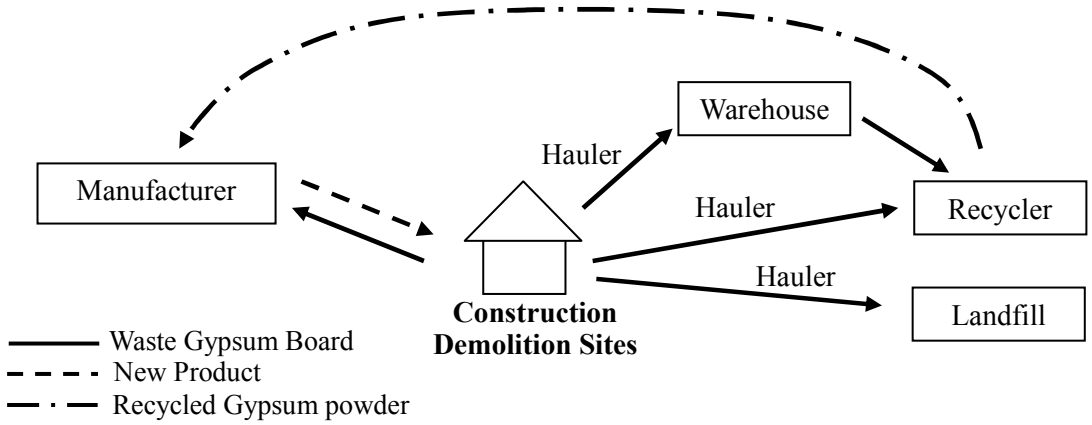


Figure 3.1 Recycling flow of gypsum board

In Ontario, there is only one gypsum recycling facility: *New West Gypsum Recycling Inc.* (New West Gypsum Recycling, N.D.) in Oakville[2]. Therefore, the wastes generated far from this recycling facility, especially from the northern part of Ontario, goes to landfills[3] (Recycling Council Ontario, 2005). In addition to this location condition, the balance between the recycling tipping fee of 57.5 CAD (Radvanyi, 2007) and the landfill tipping fee[4] highly influences the waste generator's decision of how to dispose of waste. In the case of C&D wastes, some of the wastes generated in Ontario are currently brought to the landfills in Michigan (RIS International Ltd., 2005).

At this point, it should be noted that even though the location and the number of recycling facilities are important factors for the volume of the recycled materials and the balance between haulage and greenhouse gas emissions, increasing the numbers of recycling facilities is not the crucial condition that accelerates recycling. For example, although Japan has 293 business offices which have one of the facilities for breaking, crushing, separating, and sorting the waste gypsum board (Ministry of Environment Japan, 2002), the recycling issues surrounding waste gypsum board have not been solved yet.

On the other hand, some jurisdictions such as the Vancouver area in British Columbia experienced negative consequences disposing of gypsum in landfill sites and they have banned the landfilling of gypsum board. Specifically, biological and chemical reactions from the generation of hydrogen sulfide gas emitted by the buried gypsum board can often causes odours and even human death. In 2000, 3 people who worked at a final disposal facility died because of hydrogen sulfide gas in Japan. It is estimated that gas was released from the buried wastes containing $CaSo_4$ which comes from gypsum board (Ministry of Environment Japan, 2000).

---

2. *The Town of Oakville* is located within Greater Toronto Area (GTA). A 30-minute drive from downtown Toronto and an hour's drive from the U.S. border. (Town of Oakville、2007)
3. Not only in Ontario, but much of the CRD waste generated in Canada goes to landfill. Recovery rate of gypsum wallboard in Canada is 33% where asphalt is 72% and concrete & rubble are 42%. (Recycling Council of Ontario, 2005)
4. *Tipping fee* is a price charged to deliver municipal solid waste to a lnadfill, waste-to energy facility, or recycling facility. (Energy Information Administration, 2001)

3.3 Recycling technology

The recycling process of gypsum board is as follows.

1) Separate gypsum board from other construction materials.
2) Store gypsum board at a transfer station, and then transfer it to a recycling facility.
3) Separate gypsum from the paper and remove fasteners and other attachments.
4) Gypsum is chipped or pulverized and then combined with raw gypsum for new products.

In these processes, there are two main barriers to recycling gypsum board. The first is the separation of gypsum board from other building materials that can be done on-site. As mentioned in Section 3.1, gypsum board is widely used for interior walls and as a base for tiles, and it is mixed with other materials. However, limited recognition of the importance of its separation and a lack of space for the bins prevent separation of gypsum and other building materials on-site. Proper source separation can keep value as a material for recycling by reducing contamination. Because of these damages, the waste gypsum board from demolition sites is much harder to recycle than the one from construction sites. While almost 100 per cent of gypsum board waste from the construction sites is recycled by the gypsum board manufacturers in Japanese metropolitan areas such as Tokyo, only the waste gypsum board from demolition sites is less than one tenth of the recycling from construction sites (Nishi, 2007a).

Some say source separation has not been implemented because it is time consuming and labor intensive, and it affects the price of recycled materials. However, it takes the same amount of time to pick up gypsum board and put it in a bin in any case. Therefore, source separation only depends on a space for bins and the environmental concern of waste generators.

The second barrier is the treatment on gypsum board such as water resistance covering and paint, particularly on the papers that cover the gypsum (Willow Root Environmental Limited, 2000). However, this constraint depends on the percentage

of gypsum board with treatment in the market. For instance, gypsum board with surface treatments can be recycled in Japan where 80 per cent of the all gypsum boards are regular boards and the influence of the treatments is as small (Nishi, 2007a).

3.4 Secondary products demand

Besides being combined with new gypsum board, recycled gypsum can be added as a soil amendment for agricultural purposes and as a soil improvement for high clay content soil. Recycling companies set a limitation of recycled gypsum contents in new gypsum board, because it affects the productivity of gypsum board. The residue paper contents from the wastes also affect fire-resistance. For instance, while *New West Gypsum Recycling Inc.* makes new wall board that includes in excess of 25 percent recycled gypsum (New West Gypsum Recycling, N.D.), *Yoshino Gypsum Co. Ltd.* in Japan limits recycled to a gypsum maximum of 10 per cent (Nishi, 2007a). The content of recycled materials affects consumption and demand for recycled materials. Therefore, gypsum board which can contain more recycled gypsum is one of the research and development (R&D) subjects to expand the demand for recycled materials.

3.5 Summary

The barriers to the collection and recycling processes of gypsum board are summarized below:

- Lack of on-site material separation of gypsum from other building materials.
- Technological difficulty to make high-grade recycled gypsum powder.
- Technological difficulty to recycle waste gypsum board with surface treatments.
- Competition between the tipping fees for recycling and landfill.

4. Investigation 2 : Market Building

Suppliers and consumers are the key players in the market for recycled materials just as in any other market. A supplier indicates the quality of products with a price and a consumer can then make a decision to purchase the materials. This section examines the performance of a recycler, a waste generator, and a consumer of recycled materials in terms of how they influence the establishment of the market for recycled materials. The latter part of this section also shows examples of what can improve their performance.

4.1 Performance of each player

First, a recycler accepts waste and then acts as the supplier of recycled materials. The current performance of the recycler will be constrained by the capability of collecting and recycling waste as described in Section 3. Recyclers have faced technological barriers to segregate, purify, and produce the recycled materials from the wastes that are not well separated at source from other construction materials. Technologies to generate high quality recycled materials from contaminated wastes need funds for R&D and facilities, and this affects the price of recycled materials. Even if the recycler has the facilities, it is not easy to produce high quality materials which can compete with inexpensive virgin materials.

Gypsum is one of the most abundant minerals in the world, and gypsum board is also one of the products with the lowest embodied energy[5]. Therefore, it is difficult for recycled materials to be advantageous under current conditions. These facts are reflected by the existence of only one gypsum recycling facility in Ontario and it arose in this challenging business environment. No other companies currently compete in this field and market for recycled gypsum is viewed as very small.

The second player is a waste generator who starts the recycling loop. If there

5. *Embodied energy* is the energy consumed by all of the processes related to the production of a building, from the acquisition of natural resources to product delivery.

are no mandatory recycling regulations or a ban on landfill for the wastes, waste generators decide to either recycle the waste or send it to landfills based on the landfill tipping fees.

The last player is the consumer of recycled materials, who plays a vital role in generating demand for recycled materials. Having a strong demand is a necessary factor for any kind of business. However, unless there is a regulatory incentive to choose the recycled materials, the consumer is not attracted by the recycled materials perceived as a less valued product with higher costs. The main consumer of recycled gypsum is the gypsum board manufacturers. As mentioned in Section 3.4, several applications have been developed for recycled gypsum, such as soil amendments. Practically, however, recycled gypsum is not widely used in these innovative applications. The reason for the low use of soil amendments is because recycled gypsum is not needed in large amounts and the availability of relatively inexpensive virgin materials compared to the cost of recycling and transportation to a field.

4.2 Summary

The factors that affect the performance of a recycler, a waste generator, and consumer of recycled materials are summarized below. Steps to improve the quality and the price of the recycled materials greatly depend on the waste generator and the technological capacity of the recycler. On the other hand, the performance of the consumer in closing the recycling loop can be influenced by the following outside factors:

- Competition between the prices of recycled materials and virgin materials.
- Less demand due to the processing costs and perceived lower quality of the recycled materials.
- Level of the landfill tipping fees.
- Incentives to choose the recycled materials other than consumer's preference.

4.3 Potential incentives

This section highlights an example which improved the technological capacity of a recycler and three other examples where incentives were offered to the waste generators and consumers to recycle.

4.3.1 A technological development in a recycler

A successful model which overcame the technological barrier is the performance of *Gypsum Recycling International* (GRI) in Denmark (Gypsum Recycling International, N.D.). GRI developed a patented processing unit that can recycle waste gypsum board into a high quality gypsum powder. Their container is placed on site and collects waste gypsum boards, thereby reversing the process of a typical recycling system in which the waste generator brings wastes to a warehouse. Collected waste gypsum boards are brought to the recycling facilities to store them where the mobile processing unit comes and generates the recycled powder. The recycling facilities are located near gypsum board plants and can avoid lengthy time requirements for the transportation of recycled powder. The technology allows for removal of all the types of the contaminants. As a result, up to 25 per cent[6] high quality recycled gypsum powder can be blended into new gypsum board (Gypsum Recycling International, N.D.).

In addition to the technological development by GRI, other conditions that affect the recycling process are also set in Denmark. For instance, tipping fees for landfills vary depending on the region from 100 CAD (70 EUR) to 185 CAD (130 EUR) per tonne (Nielsen, 2007) which includes landfill taxes. Compared to the tipping fees of less than $70 per tonne in Ontario and Michigan (Further detail is described in Section 4.3.2), this cost is one of the incentives for waste generators to bring their wastes to the recyclers. Plus, GRI's on-site container can protect waste gypsum boards from becoming soiled and/or breaking. Under these circumstances,

6. Recycled gypsum content in Japanese gypsum board manufactures is 5 to 10 per cent and 25 percent in Ontario.

more gypsum board waste can be brought to the recycling processes and recycled gypsum powder can compete with the virgin materials.

4.3.2 Incentive for the waste generator: Landfill

Shipping wastes from Ontario to Michigan is a considerable waste management issue in Ontario. In 2006, 9.2 million cubic metres of waste was brought to Michigan landfills from Canada (Michigan Department of Environmental Quality, 2007). Solid waste shipped from Canada has been increasing and it comprised 19.5 per cent of the solid waste disposed in Michigan (Michigan Department of Environmental Quality, 2007). C&D wastes are classified as Type III[7] waste and it reaches more than 625,000 cubic metres. The details of the wastes shipped to Michigan are indicated in Table 4.1. The majority of the increase in the wastes shipped is related to a contract with the City of Toronto and *Republic Waste Services*[8], an American company, to ship the waste from Ontario to Michigan. Considering these circumstances, Michigan will close its border in 2010 and the City of Toronto has bought Green Lane Landfill located in Southwold Township in Elgin County to prepare for this closing. The city will begin to use it in 2011 when the border is closed.

While finding an alternative landfill site, it is also important to take steps against waste going to landfills. Although Canada has difficulty finding a landfill site because of communities' unwillingness to accept the landfill in their own backyards, there is no acute geographical constraint compared to Japan and Denmark. However, there is no doubt that the landfill site impacts the natural environment and buries waste which can be recycled. Once the wastes are brought to landfills, it means a product comes to the end of its life cycle. The product brought to the landfill is deemed of no value; the tipping fee is the only consideration for waste generators. Therefore, controlling the tipping fees or

---

7. Type III wastes are certain wastes generated in industrial and construction and demolition activities. (Michigan Department of Environmental Quality, 2007)
8. *Republic Waste Services* owns the *Carleton Farms Landfill* mentioned in the later Table 4.2.

putting other conditions on the acceptance of wastes are the only ways to keep wastes out of landfills. The border closing could be a concern for Ontario, but it can be also an opportunity to review and identify other solutions for dealing with wastes.

Table 4.1(1) Solid waste shipped to Michigan from Canada (October 2005 to September 2006)

Type of waste	Volume Cubic Yards	Volume Cubic Meters
Type Ⅱ waste	11,266,527	8,613,878
Type Ⅲ waste	818,380	625,696
Total	12,084,907	9,239,574

Type Π Municipal solid waste.
Type ΙΙΙ Certain Wastes generated in industrial and construction and demolition activities.

Source: Michigan Department of Environmental Quality. (2007). Report of Solid Waste Landfilled in Michigan October 1, 2005 – September 30, 2006.

Table 4.1(2) Landfills in Michigan which accept C&D wastes from Canada (October 2005 to September 2006)

Landfill	County	Volume Cubic Yards	Volume Cubic Meters
ALLIED WASTE INDUSTRIES ROCKWOOD LANDFILL	MONROE COUNTY	315,292	241,058
BRENT RUN LANDFILL	GENESEE COUNTY	4,390	3,356
CARLETON FARMS LANDFILL	WAYNE COUNTY	410,127	313,565
CITIZENS DISPOSAL INC	GENESEE COUNTY	3,773	2,885
PINE TREE ACRES INC	MACOMB COUNTY	31,086	23,767
SAUK TRAIL HILLS LANDFILL	WAYNE COUNTY	963	736
VEOLIA ES ARBOR HILLS LANDFILL INC	WASHTENAW COUNTY	19,518	14,923
WOODLAND MEADOWS RDF-VAN BUREN	WAYNE COUNTY	33,231	25,407
	TOTAL	818,380	625,696

Source: Michigan Department of Environmental Quality. (2007). Report of Solid Waste Landfilled in Michigan October 1, 2005 – September 30, 2006.

(1) Landfill tipping fee

Inexpensive landfill tipping fees are the primary barrier to recycling. Table 4.2 indicates the landfill tipping fees of major Ontario landfills, Michigan, Japan, and Denmark. As shown in Table 4.1, *Allied Waste Industries Rockwood Landfill* and *Carleton Farms Landfill* in Michigan are the ones which accept the largest volumes of waste from Canada.

As the table illustrates, the landfill tipping fee varies from 26 CAD to 260 CAD per tonne. In the cases of Ontario, Hokkaido, Tohoku, and the San-in area in Japan, inexpensive landfill tipping fees are barriers to the promotion of recycling. For instance, while gypsum board wastes from the construction sites are almost 100 per cent recycled in the Tokyo area, in Hokkaido, Tohoku, and San-in by contrast only about 20 per cent is recycled (Nishi, 2007a). This evidence illustrates the important influence of tipping fees in encouraging recycling gypsum.

(2) Landfill tax and landfill ban

Many of European countries are applying landfill taxes. While the landfill tax means the polluter must pay, there is a concern about an increase in illegal dumping. Across the EU, high landfill taxes are associated with higher levels of waste recovery and the lowest reliance on landfills. Low levels of landfill tax tend to not be effective such as in the UK and Finland (See Figure 4.1). Two of the highest landfill taxes are applied in Denmark and the Netherlands, where landfilling of municipal waste is less than 10 per cent of the total (Bartelings, Beukering, Kuik, Linderhof, & Oosterhuis, 2005). Their tax rates in 2005 were 45 EUR (72 CAD) per tonne in Denmark and 84 EUR (134 CAD) [9] per tonne in the Netherlands (Bartelings et al, 2005). In addition to landfill taxes, some countries are also applying other policies such as landfill bans for specific waste streams or regulations on recycling to achieve the high diversion rate from landfill. Therefore, high rates of taxation and the combination with the landfill bans seem to be a successful combination (Bartelings et al, 2005).

9. Converted with the currency of January, 2005. 1 EUR equal to 1.6 CAD.

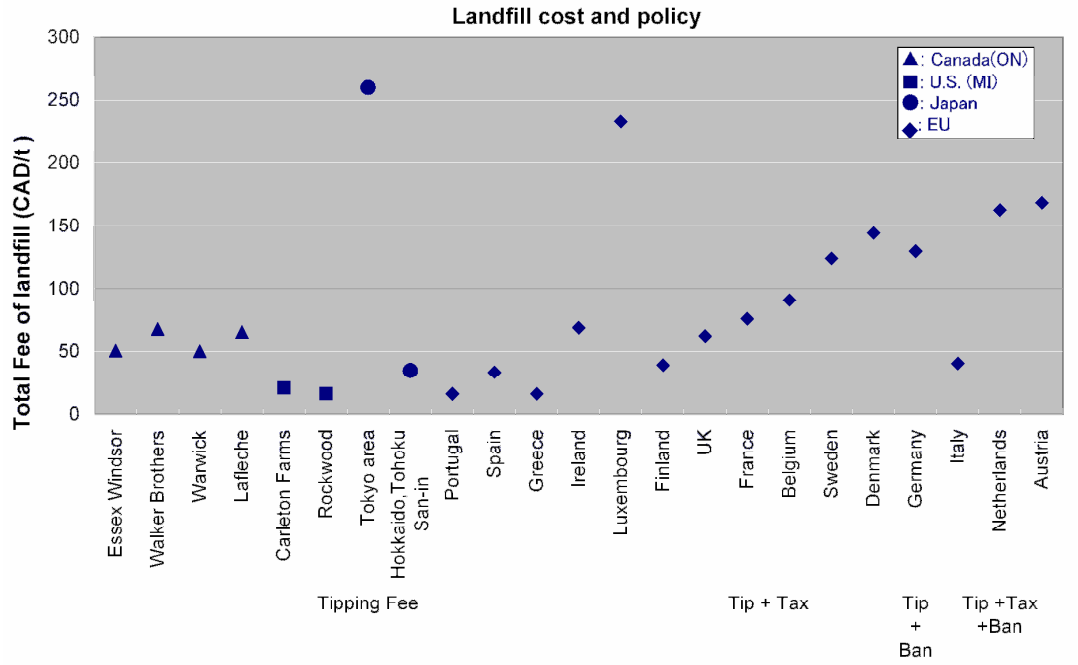
Table 4.2 Landfill tipping fees

Country / Region		Tipping fee (CAD/t)	Source
Canada (Ontario)	Essex Windsor	50.5	(Essex Windsor Solid Waste Management Authority, 2007)
	Walker Brothers in Niagara	65 – 70 (45 - 50) *[1]	(Lyng, 2007)
	Warwick	50	(Cleland, 2007)
	BFI Ridge	Based on negotiation	(Cooperberg, 2007)
	Lafleche	65 (55)*[2]	(Zimmer, 2007)
Michigan	Carleton Farms Landfill	20.61	(Daniels, 2007)
	Rockwood Landfill	16*[3]	(Dugan, 2007)
Japan	Tokyo area	260*[4]	(Nishi, 2007b)
	Hokkaido, Tohoku, San-in*[7]	26 – 43*[5]	(Nishi, 2007b)
Denmark		100 – 185*[6]	(Nielsen, 2007)

*1 $65/t to 70/t is for local customers with volume less than 500 tonnes per year. $45/t to 50/t is for out of town customers with weight more than 1000 tonnes per year. Tipping fees also vary with the type of material and the time of year.
*2 $55/t is for the large volume or long term contract
*3 Converted from 15 USD. There is no difference in tipping fees between the wastes shipped from Canada and the domestic wastes.
*4 Converted from 30,000 JPY
*5 Converted from 3,000 JPY to 5,000 JPY
*6 Converted from 70 EUR to 130 EUR. Including landfill tax
*7 Rural areas in Japan

Figure 4.1 shows the total landfill fee which is the sum of the landfill tipping fee and landfill tax in Canada, the U.S., Japan, and EU countries. From the figure, the total fee of landfills is higher in the countries which have stronger diversion policies. In other words, the total fees tend to be low in the countries that do not have taxes and bans, but Tokyo and Luxembourg are exceptional cases.

It should be noted that a landfill ban forces wastes to be recycled or incinerated regardless of the capacity of recycling and incineration (Bartelings et al, 2005). Without these conditions, a landfill ban might not be an optimal solution



Tip: Tipping fee
Tax: Landfill tax
Ban: Landfill bans for packaging or other recyclables

Sources:

1) Cost of landfill in Canada, U.S, Japan, Denmark: Referee to Table 4.1.
2) Cost of landfill in EU countries other than Denmark: Dash, R. (2003). Thematic Strategy Consultation Paper Annex.
3) Ban on landfilling: Morton, A., B. (2005). Policies to strengthen markets for recycles.

Figure 4.1 Landfill cost and policy[10]

10. See Appendix 3: Landfill cost and policy

compared to taxation. In Ontario, an incinerator in Brampton[11] is the only facility of its kind, but it does not collect any C&D waste and private wastes (Trevor, 2007). Even if it accepted C&D waste, gypsum boards might generate toxic sulfur dioxide gas (California Integrated Waste Management Board, 2006) or create problems for the lime scrubbers in the incinerator (NERC, 2006).

Unlike a control of landfill tipping fees and landfill taxes, this measure can only be applied for gypsum board waste. Considering this characteristic, advantages and difficulties in implementing a landfill ban are described below.

The first advantage is the elimination of hydrogen sulfide gas emissions. As mentioned in Section 3.2, British Columbia bans sending gypsum board to landfills because of this issue. It can be a liability issue for the government when this problem happens. Even though this gas emission issue has been known for many years, landfilling of gypsum board has been allowed and the public has been in danger without any measure taken to protect them. It is therefore not only the importance of promoting recycling, but public health that needs to be protected as well.

The second advantage for implementing a landfill ban is to have it act as a trigger to consider alternative methods. When the ban on landfilling gypsum was put into place recycling in British Columbia, all the gypsum waste went to landfills and almost no one recycled it. However, a recycled company developed a solution and convinced industries to use recycled materials (McCamley, 2007) and currently gypsum has been accepted at the landfill since February 1995 at a rate of 100 CAD per tonne and it generates revenues for the recycling companies (City of Vancouver, 2005).

On the other hand, while bans can spur innovation they can also pose a struggle for industries without enough technology to recycle gypsum board. Because of this consideration, the Japanese government has considered gypsum board as a non-mandatory recycling material. There is a difficult choice faced by

11. Brampton is located within the GTA and about 40 kilometers eastern of Toronto. The incinerator is called Energy from Waste Facility (EFW) and it incinerates non-hazardous solid waste to produce energy. The facility has been open since 1992. (Region of Peel, N.D.)

the government of either restricting the sending of gypsum board to landfills or of building demand for recycled gypsum. However, no one will develop a new product and a customer base to expand their market until it is required.

4.3.3 Incentive for the owners: The LEED Rating system

The *Leadership in Energy and Environmental Design (LEED)* rating system is run by the *Canada Green Building Council*. It measures building design and construction practices that significantly reduce or eliminate the negative impacts of buildings on the environment and occupants in five areas of Water Efficiency, Energy and Atmosphere, Materials and Resources, and Indoor Environmental Quality. Project ratings are made on the total point score and the certification is in four levels of certified, silver, gold and platinum. Waste management is included in the Materials and Resources area. It requires a waste management plan and the score is measured by a waste diversion rate. Implementation of the waste management is certified and verified by the provider's third-party rater with the documentation of check lists (U.S. Green Building Council, 2007).

The advantages in the LEED rating system are the practical indication of waste management it achieves and its motivation for building owners. Current waste audits under the Ontario Regulation 102/94 and source separation under the Regulation 103/94 are not required for all buildings' C&D waste. A typical 200-square-metre home project can be exempted from these regulations by the prescription for floor space of 2000 square metres. Furthermore, the waste management plan made in the LEED rating system requires confirmation by a third party that it has been implemented. Even though the Ontario Regulation 102/94 requires a waste audit and a waste reduction workplan, they have not been enforced and they have not been completed properly in practical projects for most of the cases. Ensuring the implementation of the workplan is also as important as, or even more so, than establishing the waste audit and the waste reduction workplan.

The second advantage are incentives to the owners of the projects to contribute a sustainable design and construction with the socially recognized LEED rating system. In this way, the waste management plan, acting upon other requirements, can be put into action by the owner's choice.

4.3.4 Incentive for the consumer: Green Procurement

Green procurement is a procurement of products and services that have a lesser or reduced adverse effect on human health and the environment and the concept is included in federal government policy. Currently, however, Green Procurement depends on contributions from each federal employee and there is no mandatory reporting framework for Green Procurement (Government of Canada, N.D.). Therefore, it is difficult to measure the implementation of Green Procurement.

Japan also has a policy called the *Law Concerning the Promotion of Procurement of Eco-Friendly Goods and Services by the State and Other Entities* (Law on Promoting Green Purchasing). Under this policy, the government and other local municipalities make a yearly plan that includes a list of products and/or services to be classified under Green Procurement (Ministry of Environment Japan, N.D.). However, recycled gypsum has not yet been included on this list. Therefore, if recycled gypsum was to be included on this list, the distribution of recycled gypsum could be enhanced.

The government is one of the biggest single consumers and by making the list of the products the government consumes transparent, the public can monitor how eco-friendly government purchasing is. For instance, the list can include information on how many products are consumed that are classified under Green Procurement regulations, which products are made and by whom, and why they were chosen. As an influence on the society, Green Procurement will be expanded to private companies and large companies have already started adopting these measures. The government can demonstrate leadership to the public ahead of a call for more Green Procurement products and services. In this way, the government can make a positive impression and the policy will be the norms for others actors in society.

5. Investigation 3 : Regulatory framework

The previous two sections have examined the industry, waste generator, and consumer behaviors. Section 4.3, in particular, outlined some potential regulatory

frameworks that can assist the waste generators and consumers to develop markets for recycled products. This section, on the other hand, examines the current regulatory framework in terms of how effectively it works to create the foundations for a recycling culture and the environment that encourages private companies to participate in the gypsum recycling business.

5.1 Data collection

Currently, there are two sources for waste estimation in Ontario. One is from a report by Ontario Ministry of Environment and the other is a report by Statistics Canada. However, there are no waste generation data collected in Ontario based on a prescribed set of rules.

The Ontario Ministry of Environment reports in *Ontario's 60% Waste Diversion Goal – A Discussion Paper* (Ministry of the Environment Ontario, 2004), that 1.6 million tonnes of recyclable materials are source separated by ICI sectors and are diverted from disposal. From an interview with the Ministry of Environment (Salamon, 2007), this was calculated based on the Waste Management Industry Survey by Statistics Canada with minor adjustment. However, details of the minor adjustment are not clear.

The second is by Statistics Canada, which is the base for the estimation by the Ontario Ministry of Environment. They published *Waste Management Industry Survey: Business and Government Sectors 2002* (Ministry of Industry Canada, 2004), and Ontario's waste was estimated. In this report, IC&I waste generated in Ontario was estimated to be 6.5 million tonnes, and 1.3 million tonnes was prepared for recycling in 2002. A method used to estimate the total amount of waste is summarized below (Forrestal, 2006).

> **Statistics Canada** (Forrestal, 2006, p.9)
> Adding the amount of waste "disposed" to the amount of waste "prepared for recycling" (diversion), any increase in waste diversion from landfill will be underestimated as a result of unrecorded recycling activities (diversion) that takes place outside the waste industry.

The estimation from Statistics Canada is based on the waste treated by the waste management industry[12]. The waste diversion activities that occurred without using services of the waste management industry are not included (See Figure 5.1). For instance, in the case that wastes are managed directly between a waste generator and a next user, diversion data is not recorded anywhere. The lack of records in these cases is especially true of large projects which have enough recyclable material to manage their wastes directly with the second user or the next projects which will make use of the materials. One of these examples was the Toronto Pearson Airport Terminal I demolition project which successfully recycled and reused its demolition materials on-site. In this project, about 200,000 tonnes of concrete from the demolition was being crushed on-site for reuse for new road construction (RIS International Ltd., 2005). This means the waste diversion activity occurred on site and was therefore outside of the waste industry's services.

Waste gypsum board that is brought back to the manufactures directly from construction sites can go through the same process of recycling as described above.

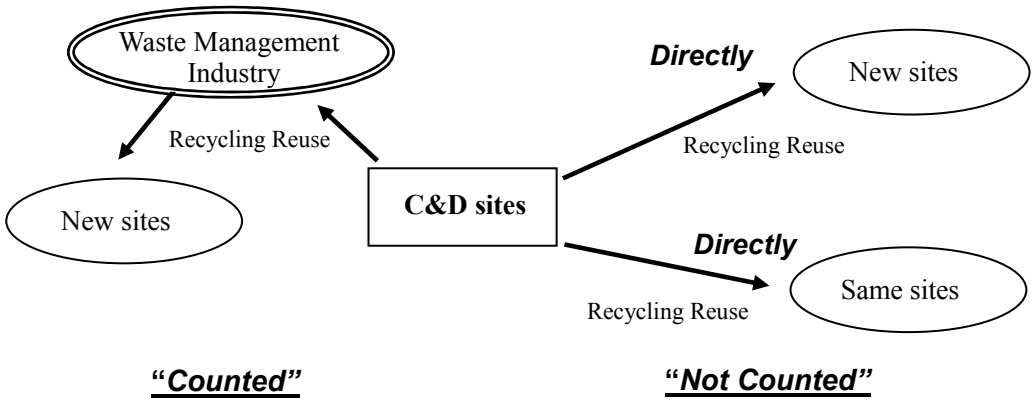


Figure 5.1 Waste activities' flow

12. In the *Waste Management Industry Survey: Business and Government Sectors 2002* (Ministry of Industry Canada, 2004), the *waste management industry* broadly includes all firms and public bodies operating in Canada that provide the services of collection, transportation, diversion, treatment or disposal of waste or recyclable materials (Ministry of Industry Canada, 2004).

Understanding the current situation with facts and figures is important. Using the collected data, analyzing and exploring the issues, as well as looking at practical solutions are ways of solving the recycling problem. Numeric data for waste management can support an analysis of regional trends, sector trends, variations between years, and the effects of policies on recycling of construction and demolition materials. In the recycling field, it is important to account for timing in order to measure the diversion rate. For instance, if waste is measured at the end of the waste flow, recyclable materials diverted at some point between waste generation and the final disposal are missed. Thus, consideration of the flow of wastes and collecting data at every critical point is essential in order to calculate an accurate recycling rate.

Another important function of collecting accurate data is to demonstrate recycling achievements to the public with hard numbers. Getting close to their recycling target can motivate industries and make them compete with each other for greater results. On the other hand, if there is no way to show the industry's results, motivation to recycle decreases for the industries because they are not being evaluated for their performance even when waste diversion has been put into action.

5.2 Response to the 3Rs Regulations

The 3Rs Regulations were brought into effect in 1994, and compliance to them had never been measured until last year. Inspections by the Ministry of Environment in 2006 revealed that more than 90 per cent of ICI groups were out of compliance with the Ontario Regulation 102/94 and 103/94 (Baker, 2007). It also disclosed the fact that many of the parties were unaware of the mandatory auditing system. The reason why this policy was not successful in making its regulations known or enforcing them is discussed in this section.

5.2.1 Obedience to the 3Rs Regulations

Regulation 102/94 concerns the completion of a waste audit and the development and implementation of waste reduction plans, and Regulation 103/94

concerns source separation. There is no need, however, to submit the waste audit and the waste reduction plans anywhere. Regulation 102/94 only requires having them available. In an event that a project is found to be out of compliance with regulations the waste generator receives a letter warning it to come into compliance within 90 days (Ministry of the Environment Ontario, 2007). Even though Ontario Ministry of the Environment Enforcement Branch of Operations Division and Regional and District Offices visits sites, checks the plans and compares them to the waste reduction activities that are actually being undertaken (Salamon, 2007), this is often done in a self-regulatory manner and this approach allows waste generators to disregard the 3Rs regulations.

When the waste generator and the hauler obey the 3Rs Regulations, recycling of C&D materials is promoted. Mandatory source separation in particular under Regulation 103/94 can protect recyclables from becoming contaminated and broken and it can also save the recycler time and effort. Waste that is not separated on source is a severe barrier for recycler's business. Only a regulatory framework can effectively manage the recyclables which are diverted from the landfill. This regulatory environment needs to be provided by the government in order to support the recycling market.

5.2.2 The recognition of the 3Rs Regulations

After the 3Rs Regulations became effective in 1994, the Ministry of the Environment enforced them only for a short period time (RIS International Ltd., 2005). Even when companies do not observe the regulations, there is no fine or charge. There could have been some measures developed to spread awareness of the importance of the 3Rs regulations and the requirements for industries, such as newsletters or periodic seminars. However, no special measures were taken and it has been difficult for waste generators to become aware of their non-compliance without notification.

5.3 Clarification of responsibility to the 3Rs Regulations

Under Regulation 102/94 and Regulation 103/94, it is not clear who is

responsible for implementing these requirements. Adherence to the 3Rs Regulations at the demolition site highly depends on specific demolition companies in charge of the project. There were some cases where the demolitionists collected wastes in only one on-site bin and told a general contractor that they would separate it later or asked a sub contractor to separate the materials. However, source separation never happened and the wastes were ultimately shipped to landfills (Renkema, 2007).

In these cases, it is not clear from the regulations' statements that these practices are out of compliance with the Regulation 103/94 and whether it is a responsibility of the general contractor, or the sub contractor who is the demolitionist. It appears an owner of the project assumes responsibility (see statements below); however, the meaning of the owner is not clear even after an interview with the Ministry of Environment Hamilton District Office (Dunn, 2007).

Ontario Regulation 102/94
….It requires *owners* to conduct the waste audit….

Ontario Regulation 103/94
….It requires *owners* to have source separation and….

Ownership has also been an issue in Japan and one of particular concern because it is connected to illegal dumping. Under the Construction Material Waste Recycling Law effective in 2000, it is the responsibility of the general contractor to manage source separation and recycling even when these activities are run by subcontractors[13]. Because of the existence of several subcontractors, the cost for an end contractor were unclear before this law was made. In the end, illegal dumping by the end contractor who did not receive enough payment became an issue (Ministry of Land, Infrastructure and Transport Japan, N.D.). With the law put into effect, the general contractors need to choose a trustworthy registered subcontractor with a fair price, otherwise the general contractor is charged when the subcontractor is out of compliance with the regulations.

13. See more detail in Appendix 2: Demolition projects procedure in Japan

This system can prevent a situation where only a demolition specialist knows how wastes are treated. At least one party, in this case the general contractor, needs to identify the overall waste flow, its treatment, and behavior of the related contractors. This notion is similar to the LEED program. Under the LEED program, an owner of a building is responsible for construction of a green building. Therefore, the owner's attention and stake in ensuring the green building will encourage them to monitor behavior of the contractors. For both cases, there is a party who acts to oversee the overall construction or demolition project with a possibility that they might be charged with improper performance or not obtain LEED certification.

Thus, it is important to recognize the connections of related parties in the construction and demolition projects and to examine who should take what kind of responsibility. For instance, responsibility can be assigned to the building owner to implement proper waste management procedures, but it could also be delegated to the general contractor. Delegation allows the building owner, who is not an expert on construction and demolition projects to entrust the waste management to the general contractor. However, assigned responsibility would allow the owner to be concerned with waste management from their construction site at initial stages of the project. As indicated in the LEED program and the Japanese regulatory framework, treatment of waste can be improved with assigning responsibility that is not directly on the construction company and/or the demolition company.

5.4 Scale limitation in the 3Rs Regulations

Coverage of the 3Rs Regulations has an influence on the number of projects and volume of wastes that are managed. Under the current Regulation 102/94 and the Regulation 103/94, only the projects whose total floor area is at least 2,000 square metres are required to conduct a waste audit, develop and implement a waste reduction plan, and have a source separation program. Furthermore, it is only applied to unpainted gypsum board for construction projects.

A typical house for a family of four is 1200 to 2000 square feet (Ministry of Energy Ontario, N.D.) which is equal to about 185 square metres; thus, the 3Rs Regulations do not account for residential housing, only large projects. According

to the *Canada Mortgage and Housing Corporation (CMHC)*, as shown in Table 5.1, 42,654 Single-Detached, Semi-Detached, and Row dwellings were under construction in December 2006 (CMHC, 2007). These types of housing are generally smaller than 2000 square feet. Therefore, these projects have been exempted from the 3Rs Regulations even though small and middle scale residential housing also generates construction wastes.

Table 5.1 (1) Statistics of dwellings completions and under constructions in Toronto

	Type	Single-Detached	Semi-Detached	Row	Apartment and Other	***Total***
December 31 2005	Dwelling Completions	16,917	3,614	5,742	13,023	39,296
	Under Constructions	9,886	1,883	4,586	27,950	44,305
December 31 2006	Dwelling Completions	14,779	3,135	5,725	14,482	38,121
	Under Constructions	9,213	1,638	4,032	27,771	42,654

Source: Canada Mortgage and Housing Corporation, (2007). CHS: Residential Building Activity – Dwelling Starts, Completions, Under Construction and Newly Completed and Unabsorbed Dwellings.

Table 5.1 (2) Total of housing in Toronto

	Type	***Total***
December 31 2005	Dwelling Completions	39,296
	Under Constructions	44,305
December 31 2006	Dwelling Completions	38,121
	Under Constructions	42,654

Source: Canada Mortgage and Housing Corporation, (2007). CHS: Residential Building Activity – Dwelling Starts, Completions, Under Construction and Newly Completed and Unabsorbed Dwellings.

The Japanese Construction Material Waste Recycling Law is applied to the projects described below. The total floor area of a typical residential house in Tokyo, Japan is 150 square metres, and thus the wastes from their construction must be recycled (PHP interface, N.D.). These regulations in Japan imply that almost all demolition projects must not mix wastes and ship them to landfills.

The Construction Material Waste Recycling Law is applied for:

1) Demolition projects where the total floor area of at least 80 square metres;
2) Construction and extension projects of at least 500 square metres;
3) Renovation projects of at least 870,000 dollars (100 million yen);
4) Construction or demolition projects for other than buildings at least 43,000 dollars (5 million yen).

The intent of the 3Rs Regulations are to reduce wastes that go to final disposals of incineration or landfill sites, to save precious natural resources, and to avoid negative environmental impacts. It is important that the regulations not be a false framework that is inadequate and not monitored properly. Even though the 3Rs Regulations were made, it makes little sense if there are many ways to deflect from compliance and only have limited demolition projects apply to it.

5.5 Summary

The barriers in creating a regulatory framework to support the recycling of gypsum board are summarized below:

- Lack of data and its manner of collection.
- Lack of enforcement of the 3Rs Regulations.
- Unclear responsibility of the 3Rs Regulations.
- Building scale restrictions for the 3Rs Regulations.

6. Concluding remarks

In the previous three sections, the main phases of collection, recycling, and purchasing in C&D waste recycling were examined and several barriers to recycling were found, as shown in Table 6.1. The barriers are, as a whole recycling system, related to two critical points which answer the central question of this inquiry.

The first point is a malfunction of the existing 3Rs Regulations. Ontario once gave attention to C&D waste and put into place the 3Rs Regulations proposed to

promote waste diversion. The adherence to these regulations has been abandoned, however, because of insufficient details within each regulation. As explained in Section 5, waste audit, source separation, and building scale restrictions for the 3Rs Regulations could have controlled the shipment of C&D wastes to the landfills and also could have more strongly encouraged the waste generator to recycle.

The second point is inexpensive landfill tipping fees that wipe out the positive effects from the 3Rs Regulations. For the private companies, economic incentives to recycle waste are important factors and their social responsibility is not always enough to motivate them to recycle waste materials.

Table 6.1 Findings from the examinations of the recycling phases

Category	**Sub-category**	**Summary**
Current regulatory framework	Related Regulations	Ontario Regulation 102/94 and 103/94 (3Rs Regulation) apply under the Environmental Protection Act.
		102/94: Requires a waste audit, development and implementation of waste reduction plan 103/94: Requires source separation
	Application of 3Rs Regulations	It is applied for Construction and Demolition projects where the total floor area is at least 2,000m^2.
	Materials to be recycled	Cardboard, Brick&Concrete, Drywall (unpainted), Steel, Wood (untreated). Drywall is exempted from demolition project
Ontario waste estimation	Solid waste	More than 12 million tonnes in 2002
	C&D waste	1.2 million tonnes with recycling rate of 12% in 2002
Examination in the recycling phases	Collection & Recycling	- Lack of source separation - Technological difficulty for recycling of gypsum board with treatments and the quality of recycled materials - Competition with landfill tipping fee
	Market	- Cost of technology affects the price of recycled materials - Competition with virgin materials - Competition with landfill tipping fees - Lack of incentive to consume recycled materials
	Regulatory framework	- Lack of data collection - Lack of enforcement of the 3Rs Regulations - Unclear responsibility for the 3Rs Regulations - Building scale restrictions for the 3Rs Regulations

Figure 6.1 illustrates a relationship between the regulatory framework and the establishment of recycling businesses. The first stage is the environment set by the government for the recycling business. Only the government can set it and the industries cannot run their business until it is provided. The second stage is business creation and competition. After the government sets the required environments, this can accelerate the technology development and competition among the private companies. The last stage is a stabilization of markets with supportive regulations.

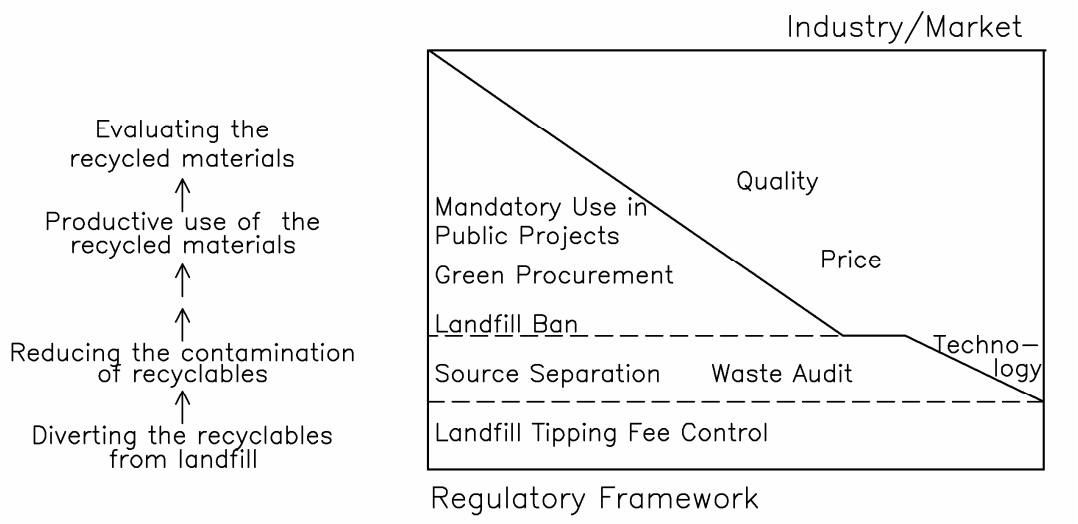


Figure 6.1 Regulatory framework and Business activity

The following are the recommendations that will enhance the development of recycling markets in Ontario. The impact from the enforcement of the existing 3Rs Regulations will generate a response from the private companies. The government must therefore rethink their waste management regulations as a starting point. This is a necessary condition for C&D waste management in Ontario which has been unnoticed for many years.

(1) Review of the 3Rs Regulations

Enforcement of the 3Rs Regulations by modifying the details of 3Rs Regulations is suggested to make sure recycling is implemented.

Mandatory reporting

A waste auditing and a waste reduction plan need to be reported to the Ministry of the Environment. With these documents the Ministry of the Environment can make sure the waste reduction plan is implemented as planed. It is also important to confirm that wastes were brought to the recycling institutions using receipts as proof.

Modification of the project scale

The application of the 3Rs Regulations need to be expanded to typical housing projects (e.g. total floor area over 200 square metres.). Gypsum board is one of the typical building materials and it is widely used in the construction of houses. Thus, waste from the construction of large buildings is not the only source of gypsum board waste; gypsum board waste from typical housing projects also needs to be managed.

Application to the demolition projects

Demolition projects need to be included in the mandatory C&D waste management projects at the same time as the enforcement of the 3Rs Regulations. Gypsum board waste from the demolition sites is now generally broken and soiled when it is taken from the site. Enforcement of the 3Rs Regulations will make ensure on-site source separation and protect gypsum board waste.

Table 6.2 Suggested materials to be recycled by establishments designated under the Ontario's 3Rs Regulations (Modification on Table 2.1)

Waste	Construction over ~~2000~~ **200**m^2	Demolition over ~~2000~~ **200**m^2
Cardboard	○	○
Brick & Concrete	○	○
Drywall (unpainted)	○	●
Steel	○	○
Wood (Untreated)	○	○

○ Required ● Required (Suggested)

(2) Landfill tax

Increasing the cost of landfilling is necessary as an economic incentive for the waste generators. Both private companies and municipalities run landfills in Ontario. Therefore, instead of setting a standard price for tipping fees, the landfill taxes make specific fees for the wastes and they also make it clear that a polluter pays an extra cost. As described in Section 4.3.2, landfill taxes and landfill bans directly effect the waste generators. In the case of Ontario, it is possible to ban landfilling gypsum board waste since the existing recycling company is *New West Gypsum Recycling Inc.* and they have already developed their technology in British Columbia where the landfilling of gypsum board has been banned. Therefore, it is assumed that they have sufficient ability to handle gypsum board waste.

However, a landfill tax would be beneficial for two reasons: the first is that the landfill tax has a similar effect as a landfill ban in decreasing waste and increasing recycling. It is also possible to add additional taxes on only gypsum board waste that is separated from other building materials by the 3Rs Regulations. These additional taxes will provide a greater incentive for the waste generators to avoid the dangerous landfilling of gypsum board waste. In this sense, landfill taxes can play the same role as landfill bans which have a negative impression as an extreme regulation.

The second reason a landfill tax is beneficial is its role in promoting the variety of recyclable materials. Gypsum board is the subject for this inquiry, but there must be other materials that are struggling to gain advantage over non-recycled products because of the inexpensive landfill tipping fees. Therefore, a landfill tax would be an opportunity for the related industries to reconsider the way to handle their wastes.

(3) Education

The Ontario Ministry of the Environment has started to have seminars on the 3Rs Regulations so that the construction and demolition sectors follow the regulations. This is an important step in rebuilding the 3Rs Regulations that has been loosely followed for more than 10 years. In addition to education for the

industries, seminars for related ministries, municipalities, and organizations also need to be considered. There were several situations evident through this research where the interpretation of the 3Rs Regulations were not clear even among the related parties which were supposed to know information on the 3Rs Regulations and transmit this information to the public. Therefore, while conducting the seminars to the construction and demolitions sectors, the education of people working for the parties which manage and observe the industries is also needed. They are expected to understand what kind of materials must be recycled, who the regulations apply to, and when and how to implement the 3Rs Regulations and guide the industries towards the proper actions. Publishing a detailed guide about the 3Rs Regulations would also be helpful to answer questions from the industries. There is an existing guide for the 3Rs Regulations, but it only shows how to conduct a waste reduction plan and auditing. This guide does not explain the interpretation of the 3Rs Regulations themselves.

(4) Industry's environmental consciousness

Source separation is the simplest and the most important behavior that private companies can take. A manager of construction and demolition projects needs to educate and train each worker for all projects that have environmental concerns as stipulated by the Ontario Ministry of Environment. They also need to give attention to having enough bins for source separation and site planning to make a space for them in advance. In the case that it is impossible to have them on site, a nearby area to put them temporarily or choosing a trustworthy subcontractor to source separate later from a bin can be considered.

Acknowledgements

I would like to express my gratitude to Dr. Brian Baetz and Dr. Gail Krantzberg at McMaster University who guided me in the completion of this inquiry through discussion and feedback.

I would also like to thank Ms. Karen Renkema, Mr. Henrik Lund-Nielsen, Mr. Shawn Radvanyi, and Ms. Vera Rocca for their kindness in providing me with valuable information and support which allowed me to carry out this research.

References

Baker, B. (2007, March 17). ICI: clean up your act; Michigan move to ban Ontario trash worrisome. *Daily Commercial New,* Retrieved June 7, 2007, from http://dcnonl.com/article/id20429&search_term=ICI%20clean%20up%20your%20act

Bartelings,H., Beukering, P.V., Kuik, O., Linderhof, V., & Oosterhuis, F. (2005). Effectiveness of landfill taxation, Report prepared for the Dutch Ministry of Housing, Spatial Planning and the Environment, *Institute for Environmental Studies, Vrije Universiteit, Amsterdam,* Retrieved June 21, 2007, from http://www.ivm.falw.vu.nl/Research_projects/index.cfm/home_subsection.cfm/

California Integrated Waste Management Board. (2006). *Wallboard (Drywall) Recycling,* Retrieved June 21, 2007, from http://www.ciwmb.ca.gov/ConDemo/Wallboard/

Canada Mortgage and Housing Corporation. (2007). *CHS-RESIDENTIAL BUILDING ACTIVITY Dwelling Starts, Completions, Under Construction and Newly Completed and Unabsorbed Dwellings- 2006*, Retrieved June 15, 2007, from http://www.cmhc-schl.gc.ca/en/hoficlincl/homain/stda/index.cfm

City of Vancouver. (2005). *Vancouver Landfill 2005 Annual Report.* Retrieved June 29, 2007, from http://vancouver.ca/engsvcs/solidwaste/landfill/report.htm

Cleland, R. (2007). Personal contact on June 20, 2007, District Manager, Waste Management, Southwestern Ontario Landfills. RCLELAND@wm.com

Cooperberg, C. (2007). Personal contact on June 13, 2007, Director, BFI Canada Income Fund, Investor Relations & Corporate Communications, chaya.cooperberg@bficanada.com

Daniels, C. (2007). Personal contact on June 25, 2007, Manager, City of Toronto, Solid Waste Management Services, Operations Support, daniels@toronto.ca

Dash, R. (2003). Thematic Strategy Consultation Paper Annex. *European Commission Environmental DG.* Retrieved June 23, 2007, from http://ec.europa.eu/environment/waste/consultation_comments.htm

Dillon Consulting Limited. (2004). *Regent Park Redevelopment Project Sustainable Community Design Appendix6: Demolition & Construction Waste.* Retrieved May 11, 2007, from http://www.regentparkplan.ca/sustainability.htm

Dugan, P. (2007). Personal contact on June 15, 2007, Walker Environmental Group, Tel: 734-231-9913

Dunn, M. (2007). Personal contact on June 19, 2007, Ontario Ministry of the Environment, Hamilton District Branch. Tel: 905-521-7650

Energy Information Administration. (2001, February). *Glossary*, Retrieved May 10, 2007 http://www.eia.doe.gov/cneaf/solar.renewables/rea_issues/glossary.html

Essex Windsor Solid Waste Management Authority. (2007). *Tipping Fees For Essex-Windsor Regional Landfil,.* Retrieved June 8, 2007, from http://www.ewswa.org/pages/landfill/rl.html

Forrestal, B. (2006). Does An ICI Waste Diversion Target Make Any Sense? *Waste EDGE: The official publication of the Ontario Waste Management Association,* Vol.2 No.1 Spring/Summer, pp. 8-14 Retrieved June 11, 2007, http://www.owma.org/db/db2file.asp?fileid=403

Government of Canada. (N.D.). *Green Government Procurement,* Retrieved June 1, 2007, http://www.greeninggovernment.gc.ca/default.asp?lang=En&n=256986C5-1

Gypsum Recycling International. (N.D.). *The Gypsum Recycling System,* Retrieved June 3, 2007, from http://www.gypsumrecycling.biz/

Kelleher Environmental. (2005). *IC&I Sector Consultation Session To Discuss Options to Achieve 60% Diversion of Waste In Ontario.* Retrieved May 10, 2007, from http://www.solidwastemag.com/PostedDocuments/PDFs/2006/01Jan/KelleherICIReportMOE.pdf

Lafarge North America. (2007). *Product Information: Regular Drywall.* Retrieved July 25, 2007, from http://www.lafargenorthamerica.com/wps/wcm/resources/file/eb656f4d08e35cf/Regular%20Drywall_Submittal.pdf

Lyng, J. (2007). Personal contact on June 12, 2007, Walker Environmental Group, customerservice@niagarawastesystems.com

McCamley, G. (2007). Personal contact on June 28, 2007, New West Gypsum Recycling. mccamley@nwgypsum.com

Michigan Department of Environmental Quality. (2007). *Report of Solid Waste Landfilled in Michigan October 1, 2005 – September 30, 2006,* Retrieved June 9, 2007, from http://www.deq.state.mi.us/documents/deq-whm-stsw-ReportSolidWasteLandfilledFY2006.PDF

Ministry of Energy Ontario. (N.D.). *Backgrounder; Ontario Energy Board Amendment Act, 2003 :Household Impact Case Studies.* Retrieved July 25, 2007, from http://www.energy.gov.on.ca/index.cfm?back=yes&backgrounder_id=32&fuseaction=english.news&news_id=41

Ministry of Environment Japan. (2000). *A Report of a Board for Hydrogen Sulfide Gas Emission in Landfill Sites (Translation of 廃棄物最終処分場における硫化水素対策検討解報告書骨子).* Retrieved June 5, 2007, from http://www.env.go.jp/recycle/kosei_press/h000906a.html

Ministry of Environment Japan. (2002). *A Survey of Promotion of the Waste Gypsum Board Recycling (Translation of 廃石膏ボードのリサイクルの推進に関する検討調査). Waste Management and Recycling Department (Translation of 廃棄物・リサイクル対策部).* Retrieved June 2, 2007, from http://www.env.go.jp/recycle/hokokusho.html

Ministry of Environment Japan. (N.D.). *GreenPurchasing.net,* Retrieved May 31, 2007, from http://www.env.go.jp/policy/hozen/green/g-law/index.html

Ministry of Industry Canada. (2004). *Waste Management Industry Survey: Business and Government Sectors 2002*. (Catalogue No. 16F0023XIE ISSN1701-5677). Retrieved May 13, 2007, from http://www.statcan.ca/bsolc/english/bsolc?catno=16F0023X&CHROPG=1

Ministry of Land, Infrastructure and Transport Japan. (2006). Future trend of construction by-products. (Translation of "建設副産物に関する今後の動向"), *Policy Bureau (Translation of 総合政策局)*. Retrieved May 10, 2007, from http://www.mlit.go.jp/sogoseisaku/region/recycle/fukusanbutsu/genjo/index.htm

Ministry of Land, Infrastructure and Transport Japan. (N.D.). *A Demolition Waste Recycling Program. (Translation of "建築廃棄物リサイクルプログラム").* Retrieved June 13, 2007, from http://www.mlit.go.jp/sogoseisaku/region/recycle/recyclehou/recycle_kihon/111004_02.htm

Ministry of the Environment Ontario. (2004). *Ontario's 60% Waste Diversion Goal – A Discussion Paper.* Retrieved May 11, 2007, from http://www.solidwastemag.com/PostedDocuments/PDFs/OntDiv.pdf

Ministry of the Environment Ontario. (2007). *Ontario Regulations 102, 103, and you! Here's how you can prepare. Presentation to COCA. June 15, 2007*, Retrieved Julne 13, 2007, from http://209.200.67.168//Data/News/Ontario%20Regulations%20102%20103%20and%20You.pdf

Morton, A., B. (2005). Policies to strengthen markets for recycles. *Department of Civil, Construction and Environmental Engineering, North Carolina State University, U.S.*, Retrieved June 21, 2007, from http://www.earthscan.co.uk/news/article/mps/UAN/453/v/1/sp/

NERC. (2006). *Gypsum Wallboard Waste Management in the Northeast*, Retrieved June 21, 2007, from http://www.nerc.org/documents/gypsum-july_2006.html

New West Gypsum Recycling. (N.D.). *The Gypsum Recycling Process*. Retrieved May 26, 2007, from http://www.nwgypsum.com/english/rp_01.htm

Nielsen, L., H. (2007). Personal contact on June 4, 2007, CEO, Gypsum Recycling International A/S, hln@gipsrecycling.dk

Nishi, M. (2007a). Yoshino Gypsum Co. Ltd. Engineering Department (Translation of 技術本部), Personal contact on May 28, 2007, tech@yoshino-gypsum.com

Nishi, M. (2007b). Personal contact on May 29, 2007, Yoshino Gypsum Co. Ltd., Engineering Department (Translation of 技術本部), Tel: +81-3-3890-2063

PHP interface. (N.D.) *International comparison of the housing price in major cities (Translation of 各都市の戸建て住宅価格の国際比較)*. Retrieved June 18, 2007, from http://www.php.co.jp/fun/the21/detail.php?page=99-12-1.html

Radvanyi, S. (2007). Personal contact on May 24, 2007, Recycling Services Manager, New West Gypsum Recycling Inc. sradvanyi@nwgypsum.com

Recycling Council of Ontario. (2005). Let's climb another Molehill, *Natural Resource Canada*. Retrieved May 10, 2007, from http://www.recycle.nrcan.gc.ca/summaries_e.htm

Region of Peel. (N.D.). *Algonquin Power Energy From Waste Facility*, Retrieved June 18, 2007, from http://www.region.peel.on.ca/pw/waste/facilities/algonquin-power.htm

Renkema, K. (2007) Personal contact on June 4, 2007, Council of Ontario Construction Association, krenkema@coca.on.ca

RIS International Ltd. (2005). *The Private Sector IC&I Waste Management System in Ontario*. Retrieved May 9, 2007, from http://solidwastemag.com/PostedDocuments/PDFs/2005/AprMay/ICIPrivateSectorWasteStudy.pdf

Salamon, I. (2007). Personal contact on June 21, 2007, Senior Economist, Ministry of the Environment Ontario, Waste Management Policy Branch. Ilan.Salamon@ontario.ca

Town of Oakville. (2007). *About Oakville*, Retrieved May 19, 2007, from http://www.oakville.ca/aboutoakville.htm

Trevor, B. (2007). Personal contact on June 21, 2007, Region of Peel, Waste Management Program Planning, Trevor.Barton@peelregion.ca

U.S. Green Building Council. (2007). *LEED for Homes Program Pilot Rating System Version 1.11a*, Retrieved May 31, 2007, from http://www.usgbc.org/ShowFile.aspx?DocumentID=2267

Willow Root Environmental Limited. (2000). *Construction, Renovation And Demolition Wastes Market Profile Report.* Retrieved May 21, 2007, from http://www3.gov.ab.ca/env/waste/aow/crd/publications/CRD_Market_Profiles_Report.pdf

Zimmer, M. (2007). Personal contact on June 8, 2007, General Manager, Lafleche Environmental, Inc., mzimmer@laflecheenvironmental.com

Bibliography

Brian, B. (2007, March 13). ICI: clean up your act Michigan move to ban Ontario trash worrisome, *Daily Commercial News*.

Canada Green Building Council. (2007). http://www.cagbc.org/

Center for Sustainable Systems. (N.D.). Recycling and Reuse Module:B Construction and Demolition (C&D) Recycling. Appendix. *University of Michigan* Retrieved May 23, 2007, from http://www.umich.edu/~nppcpub/resources/compendia/architecture.html#ranr

Clinch, J.P., & Gooch, M., (2007). Landfill Tax (EU). *Economic Instruments in Environmental Policy.* Retrieved June 21, 2007, from http://www.economicinstruments.com/

Emma, M. (2000). Gypsum Wallboard Recycling and Reuse Opportunities in the State of Vermont, *Waste Management Division Vermont Agency of Natural Resources.* Retrieved May 21, 2007, from http://www.cis.tennessee.edu/library/pdf/Vermont_Gypsum_Recycling.pdf

Gillespie, K. (2006, October 2). Ontarians trashing recycling targets. *Toronto Star*, pp.A15

Japan Construction Material & Housing Equipment Industries Federation. (2004). *A Report about Building Material Recycling System: A Survey of the Promotion of Construction Waste Recycling From A New Residential Housing Construction. (Translation of "建築資材リサイクルシステム調査研究報告書：新築戸建て住宅の建設工事現場から発生する建設廃棄物のリサイクル推進方策の検討"),* Retrieved May 10, 2007, from http://www.meti.go.jp/policy/recycle/main/data/research/

Ministry of Environment and Energy Ontario. (N.D.). *A Guide to waste Audits and Reduction Workplans for Construction and Demolition Projects* (Publication No. PIBS 2481e). Retrieved June 12, 2007, from http://209.200.67.168//Data/News/MOE%20Waste%20Audit%20and%20Reduction%20Guideline.pdf

Ministry of Land, Infrastructure and Transport Japan. (2002). *A Promotion Plan of Construction and Demolition Waste Recycling 2002. (Translation of "建設リサイクル推進計画 2002").* Retrieved May 10, 2007, from http://www.mlit.go.jp/sogoseisaku/region/recycle/recyclehou/recycle_kihon/kumi.htm

Ministry of the Environment Ontario. (2006, August 31). *How Ontario manages its waste: The Basic facts and figures.* Retrieved June 5, 2007, from http://www.ene.gov.on.ca/envision/news/2006/083101.htm

Appendix 1: Regulatory framework in Japan

In Japan, 75 million tonnes (20 per cent of 412 million tonnes of the total industrial waste) of C&D waste was generated in 2003 and 7 million tonnes (20 per cent of 40 million tonnes of the total final disposal of industrial waste) went to final disposal in 2002 (Ministry of Land, Infrastructure and Transport Japan, 2006). One of the serious issues in Japan was illegal dumping and 90 per cent of the illegal dumping was caused by C&D waste which rose to 3.54 million tonnes in 2004. The shortage of landfill sites because of the geographical constraints and illegal dumping were the main reasons to create the new *Construction Material Waste Recycling Law* in 2002.

1. Regulatory Framework

Construction Material Waste Recycling Law (建設リサイクル法) became effective in 2000 under *The Basic Environment Law* (環境基本法). Under *The Basic Environment Law*, *Waste Disposal and Public Cleansing Law* (廃棄物処理法) regulates proper disposal and facilities while *Law for the Promotion of Effective Utilities of Resources* (資源有効利用促進法) specifies products, industries, and materials that should be recycled. Following these two laws, the *Construction Material Waste Recycling Law* was introduced to promote material recycling and proper disposal of construction waste. Figure 1 shows a overview of the laws.

2. Construction Material Waste Recycling Law

(1) Mandatory sorted demolition and recycling wastes related to the buildings.
(2) Ensure the practical measures to have source separation and recycling.
(3) Making a registration system of demolition agents.
(4) Conducting a promotion of recycling and a use of recycled materials

Source: Ministry of Land, Infrastructure and Transport Japa,. (N.D.b).

Figure 1.1 Japanese Regulatory Framework for Recycling

Source: Ministry of Land, Infrastructure and Transport Japan, (N.D.a).

3. Application of the Construction Material Waste Recycling Law

It is applied for the specified materials for certain scale of the projects.

- Building demolition: floor area at least 80 square metres.
- New housing construction: floor area at least 500 square metres.
- Housing renovation: Total cost at least 100,000,000 yen (1 million dollars)
- Infrastructure: Total cost at least 5,000,000 yen (50,000 dollars)

Source: Ministry of Land, Infrastructure and Transport Japan, (2000)

4. Subjected materials

- Concrete
- Wood
- Asphalt
- Building materials made by concrete and steel

Source: Ministry of Land, Infrastructure and Transport Japan, (N.D.c)

5. Penalty

Disobedience to the Construction Waste Recycling Law regulates Mandatory and related regulations are fined maximum 500 thousand yen (5000 dollars).

Source: Ministry of Land, Infrastructure and Transport Japan, (N.D.d)

6. Issues

Even though the stricter Construction Waste Recycling Law was set, there have been some remaining issues.

- **Increase of mixed material wastes**

  After separation of mixed material wastes, each kind of waste becomes reduced in volume and the current collection system with large trucks is inefficient. Therefore, a collection system for small quantities of wastes is under development. Mixed material wastes are expected to undergo mandatory separation in the near future.

- **A lack of channel to connect recycling and sales of recycled materials**

  Especially, there is little demand for recycled wood pieces.

Sources:

Ministry of Land, Infrastructure and Transport Japan. (2000). Operation of the r*egulations related to the material recycling used for the building construction. (Translation of "建設工事に係る資材の再資源化等に関する法律施行令")*. Retrieved May 20, 2007, from http://www.mlit.go.jp/sogoseisaku/region/recycle/pdf/recyclehou/hourei_kokuji/seirei1412.pdf)

Ministry of Land, Infrastructure and Transport Japan. (N.D.a). Regulatory framework to establish a recycling-based society. *(Translation of "循環型社会の形成の推進のための法体系")*. Retrieved May 20, 2007, from http://www.mlit.go.jp/sogoseisaku/region/recycle/recyclehou/recycle_kihon/hotai.htm)

Ministry of Land, Infrastructure and Transport Japan. (N.D.b). *Basic principle of Construction Material Waste Recycling Law. (Translation of "建設リサイクルの基本方針")*. Retrieved May 20, 2007, from http://www.mlit.go.jp/sogoseisaku/region/recycle/recyclehou/recycle_kihon/kenriho.htm)

Ministry of Land, Infrastructure and Transport Japan. (N.D.c). *Government ordinance for the effective date of the regulation related to the material recycling used for the building construction. (Translation of "建設工事に係る資材の再資源化等に関する法律の施行期日を定める政令")*. Retrieved May 20, 2007, from http://www.mlit.go.jp/sogoseisaku/region/recycle/recyclehou/hourei_kokuji/kizitsu.htm)

Ministry of Land, Infrastructure and Transport Japan. (N.D.d). The r*egulations related to the material recycling used for the building construction. (Translation of "建設工事に係る資材の再資源化等に関する法律")*. Retrieved May 20, 2007, from http://www.mlit.go.jp/sogoseisaku/region/recycle/recyclehou/hourei_kokuji/houritsu01.htm)

Appendix 2: A flow of demolition projects in Japan

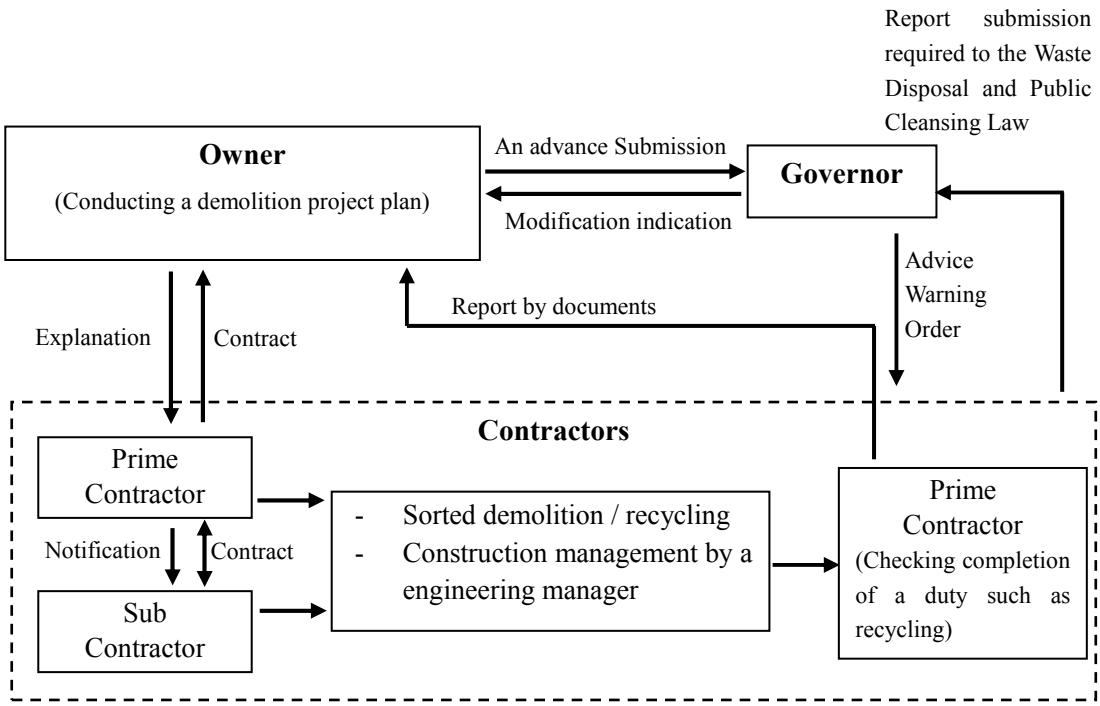


Figure 2.1 A flow of demolition projects in Japan

Source:

Ministry of Land, Infrastructure and Transport Japan. (N.D.). *Basic principle of Construction Material Waste Recycling Law. (Translation of "建設リサイクルの基本方針").* Retrieved May 23, 2007, from http://www.mlit.go.jp/sogoseisaku/region/recycle/recyclehou/recycle_kihon/kenriho.htm

Appendix 3: Landfill cost and related policy

Table 3.1 Landfill cost and related policy

Country / Region	Landfill	Tax	Ban	Policy *2	Tipping Fee (CAD/t)	Total Fee *1	
						(EUR/t)	(CAD/t)
Canada (Ontario)	Essex Windsor			Tipping Fee	50.5	-	50.5
	Walker Brothers				65 – 70	-	67.5
	Warwick				50	-	50
	Lafleche				65	-	65
U.S. (Michigan)	Carleton Farms				20.61	-	20.61
	Rockwood				16	-	16
Japan	Tokyo area				260	-	260
	Hokkaido,Tohoku San-in				26 – 43	-	34.5
EU	Portugal				-	11	15.8
	Spain				-	23	33.1
	Greece				-	11	15.8
	Ireland				-	47.5	68.4
	Luxembourg				-	162	233.3
	Finland	●		Tip + Tax	-	27	38.9
	UK	●			-	43	61.9
	France	●			-	52.5	75.6
	Belgium	●			-	63	90.7
	Sweden	●			-	86	123.8
	Denmark	●			-	70-130	144
	Germany		●	Tip + Ban	-	90	129.6
	Italy	●	●	Tip +Tax +Ban	-	28	40.3
	Netherlands	●	●		-	113	162.7
	Austria	●	●		-	117	168.5

*1 Total Fee is the sum of the landfill tipping fee and landfill tax. It is the average if the prices have ranges.

*2 Tip: Tipping fee
Tax: Landfill tax
Ban: Landfill bans for packaging or other recyclables

Sources:

Cost of landfill in Canada, U.S, Japan, and Denmark: Referee to Table 3.1. in the section3.

Cost of landfill in EU countries other than Denmark: Dash, R. (2003). Thematic Strategy Consultation Paper Annex. European Commission Environmental DG. Retrieved June 23, 2007, from http://ec.europa.eu/environment/waste/consultation_comments.htm

Ban on landfilling: Morton, A., B. (2005). Policies to strengthen markets for recycles. Department of Civil, Construction and Environmental Engineering, North Carolina State University, U.S, Retrieved June 21, 2007, from http://www.earthscan.co.uk/news/article/mps/UAN/453/v/1/sp/

Appendix 4: Cost comparison between landfill and recycling of gypsum board

Below is a cost comparison between landfilling and recycling of gypsum board using the tipping fees and a transportation fee of 50 $CAD.

Table 4.1 Gypsum board cost comparison

Gypsum board Characteristics	Thickness		inch	1/4	3/8	1/2
	Weight		kg/sheet	16.0	18.9	23.2
Cost per sheet	Recycling		$/sheet	1.7	2.0	2.5
	Landfill	Warwick	$/sheet	1.6	1.9	2.3
		Rockwood landfill	$/sheet	1.1	1.2	1.5

(Gysum board characteristics are from Lafarge Regular Drywall)

Table 4.2 Gypsum board cost comparison (details)

Recycling		Tipping fee	$/t	57.5
		Transportation	$	50.0
		Total	$/t	**107.5**
Landfill	Warwick	Tipping fee	$/t	50.0
		Transportation	$	50.0
		Total	$/t	**100.0**
	Rockwood landfill	Tipping fee	$/t	16.0
		Transportation	$	50.0
		Total	$/t	**66.0**