Gypsum Wallboard: A Study Examining Wallboard Waste Management Options for Southern Ontario

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

In 2005, the Recycling Council of Ontario published a report that identified the construction industry as one sector that did not manage its waste in an environmentally appropriate manner. In this report, *Let's Climb Another Molehill*, 15 case studies were executed to understand why this industry was neither handling nor disposing its waste properly in Southern Ontario. A set of generic recommendations was generated to help improve the management of this industry's waste. Unfortunately the scope of the report was too broad to support conclusions about the management of specific types of problematic construction waste. The aim of this thesis is to narrow what was done in *Let's Climb Another Molehill* to focus only on gypsum wallboard. The purpose of this research is to determine what options are the most desirable and feasible to deal sustainably with gypsum wallboard waste in Southern Ontario, both now and in the future. All recommendations offered are case specific.

A number of methods have been utilized to obtain the information needed to formulate appropriate recommendations to deal with wallboard. Information learned through the literature, witnessed through the observation sessions, and acquired through the interviews led to two unique option categories: 1) alternative materials and 2) change in practices. To evaluate these options, a set of criteria was created based on the concepts of sustainability and integrated waste management (IWM). This sustainable IWM criteria set allowed for consistent evaluation of the options. To improve the recommendations, the sustainable IWM criteria were refined to better deal with each of the two categories of options. When the sustainable IWM criteria for evaluating alternative materials were applied, gypsum wallboard was found still to be the best interior wall material to use today. However, applying the sustainable IWM criteria for evaluating change in practices showed that the problem with using this product lies with its management and, therefore, the remaining recommendations focus on improving the creation, use and disposal of wallboard. Many of these recommendations can easily be adopted to help eliminate inappropriate wallboard management practices. This research was able to identify areas where problems arose and to offer feasible options to improve environmentally inappropriate behaviors associated with wallboard management. Although numerous recommendations are offered, the three fundamental recommendations that will lead to the biggest change include: 1) greater number of educational programs devoted to the construction industry; 2) stricter regulations and better enforcement; and 3) a dramatic increase in landfill tipping fees. If these three recommendations were implemented, it is believed that they will play a positive role in managing gypsum wallboard waste in a more sustainable manner.

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Glossary

Carbon cycle – “A process related to the constant exchange of carbon between different sources. Carbon sinks are elements in the carbon cycle that are able to capture carbon dioxide and reduce its concentration in the atmosphere. Forests are a carbon sink—they take in carbon dioxide and convert it to wood, leaves and roots. They are also a carbon source—they release stored carbon into the atmosphere when they decompose or burn” (CWC, 2008, pg. 21)

CARS (credibility, accuracy, reasonableness, and support) – checklist in determining the trustworthiness of an article

1. Credibility signs – the author/organization provides contact information, author/organization has a good reputation in the field, and information in the article is cited
2. Accuracy signs – timelessness of the article (when was the article was published), comprehensiveness of the information presented, information presented is accurate today and not yesterday, and finally who is the article’s intended audience and was it successful in communicating these ideas to that audience
3. Reasonableness signs – information is presented in a fair manner in which there is a even balance, biases are minimal, any claims that are made are believable and do not run against the norms, and the information that is present is consistent with what other articles are stating
4. Support signs –information in the article is sourced, a bibliography is provided at the end of work, and confirmation of the accuracy of the sourced information (Harris, 2007 pgs. 3-11)

Clean wallboard – new wallboard that is uncontaminated with paint, nails, screws, dirt, and so forth (Environment Canada, 2003)

Construction, Renovation, and Demolition Waste – is waste that is generated at construction, demolition, renovation, and repair projects. The typical types of waste produced include: wood, gypsum wallboard, glass, brick, metals, plastics, rubble, roof, and miscellaneous items such as ceramic tile, fixtures, etc… (Recycling Council of Ontario, 2005; Smith-Pursley, 1997)

Contaminated wallboard that can be recycled – wallboard that is contaminated by nonhazardous materials such as: paint, decorative overlays, nails, and/or screws (New West Gypsum Employee, 2009; Sittler Employee, 2009; Waring, 2009).

Contaminated wallboard that cannot be recycled – wallboard that is contaminated by hazardous materials such as: asbestos and lead paint (New West Gypsum Employee, 2009; Sittler Employee, 2009; Waring, 2009).

Disposal – is the process of getting rid of existing waste by means of landfilling, recycling, and/or incineration (Tchobanoglous and Kreith, 2002).

Fire resistant rating – “means the time in hours … that a material or assembly of material will withstand the passage of flame and the transmission if heat when exposed to fire under specific conditions of test performance criteria, or as determined by extension or interpretation of information derived therefrom as prescribed in this code (Ontario Building Code, 2007 pg. 1-7).

Landfill – are engineered disposal sites where waste is taken for final burial (Waste Management, 2008)

Recover – is the separation of materials from the regular waste stream in order to extract any useful materials or energy from that material (Tchobanoglous and Kreith, 2002).

Recycle – “the process of collecting, sorting, cleansing, treating, and reconstituting materials that would otherwise become solid waste, and returning them to the economic mainstream in the form of raw material for new, reused, or reconstituted products that meet the quality standards necessary to be used in the marketplace” (California Integrated Waste Management Board, 2008).

Reduce – The process of diminishing the amount of waste generated (Waste Management, 2008).

Reuse – “The recovery or reapplication of a package or product for uses similar or identical to its originally intended application, without manufacturing or preparation processes that significantly alter the original package or product” (California Integrated Waste Management Board, 2008).

Scraps – are either products that have finished their useful life or by-products of new products that are being manufactured (Tchobanoglous and Kreith, 2002).

Tipping Fee – “fee, usually dollar per ton, for the unloading or dumping of waste at a landfill, transfer station, recycling center, or waste-to-energy facility (Tchobanoglous and Kreith, 2002, pg. A.17).

Wallboard/Plasterboard/Drywall – Is a type of wall structure that is typically used in the construction of interior walls in most types of building. It composition is 92% gypsum (calcium sulfate dehydrate), 7% paper, and 1% of impurities (Marvin, 2000).

Waste Diversion – diverting solid waste away from landfills by encouraging source reduction, recycling, and compositing management approaches (Tchobanoglous and Kreith, 2002)

Waste Prevention – Actions and decisions that reduce the amount of waste generated (California Integrated Waste Management Board, 2008).

Waste reduction – “the prevention or restriction of waste generation at its source by redesigning products or the patterns of production and consumption” (Tchobanoglous and Kreith, 2002).

List of Acronyms and Units of Measure

BCA	Building Code Act
^{o}C	Degrees Celsius
CARS	Credibility, Accuracy, Reasonableness and Support
$CaSO_4 \bullet 2H_2O$	Calcium Sulphate Dehydrate
$CaSO_4 \bullet ½H_2O$	Hemihydrate Gypsum
CDN	Canadian
C&D	Construction and Demolition
cm	Centimeters
CO	Carbon Monoxide
COx	Carbon Oxides
CO2	Carbon Dioxide
CRD	Construction, Renovation and Demolition
EPA	Environmental Protection Act
ft	Feet
ft^2	Square Feet
in.	Inch
IWM	Integrated Waste Management
km	Kilometers
LCA	Lifecycle Assessment
m	Meter
m^2	square meters
MDF	Medium-density Fiberboard
Mj	Mega Joules
MOE	Ministry of Environment
MSW	Municipal Solid Waste
NOx	Nitrogen Oxides
NWG	New West Gypsum

OBC	Ontario Building Code
OGCA	Ontario General Contractors Association
OSB	Oriented Strand Board
PM	Particular Matter
ppm	Parts Per Million
RCOs	Regenerative Catalytic Oxidizers
RTOs	Regenerative Thermal Oxidizers
SOx	Sulphur Oxides
TCOs	Thermal Catalytic Oxidizers
US	United States
VOCs	Volatile Organic Compounds

Chapter 1: Introduction

1.1 Background

The utilization of calcium sulphate dihydrate ($CaSO_4 \cdot 2H_2O$) or gypsum as a type of building material has been well-documented throughout history. Records dating back to 6000 B.C. indicate that the inhabitants of Anatolia, which is part of modern-day Turkey, relied on this mineral in the construction of their structures. The early application of gypsum minerals as a building material was not restricted to Western Asia, but was also found throughout the pyramids of Egypt and sculptures of Greece (Olsen, 2001; Panagapko, 2006; Sittinger and Sittinger, 2005).

Gypsum is one of the most abundant minerals found on Earth with deposits located in all six continents (Olsen, 2001). It is formed through the continuous cycle of evaporation and precipitation on sedimentary rock beds, which are located in marine basins (Panagapko, 2006). Gypsum mineral is an ideal building material for a number of reasons including: strength, ability to be manipulated into numerous shapes, fire and sound resistance, high insulation capacity, and natural abundance. It is also economical to manufacture (Gardner, 2004; Olsen, 2001; Panagapko, 2006).

The construction industry's widespread acceptance of gypsum has led to this mineral being extracted at unprecedented levels to meet increasing demands (Sittinger and Sittinger, 2005). The construction industry favors gypsum wallboard because of its low purchasing cost, ease of installation, high employee familiarity, limited disposal regulations, and low disposal fees. To reduce some of the adverse environmental problems connected with mineral extraction (see section 5.4.1), synthetic gypsum has been created. This latter gypsum is made using the by-products collected from coal-fired power plants (Nature's Way Resources, no date; Olsen, 2001; Panagapko, 2006). Although synthetic gypsum has proven to be successful in combating some of the environmental ills associated with the mining of natural gypsum, it has in no way dealt with the issues connected with disposal of gypsum wallboard (Recycling Council of Ontario, 2005).

The use of wallboard during construction, renovation, and demolition (CRD) projects has resulted in the creation of enormous quantities of drywall waste each year. The average weight of drywall discarded on a project site is one pound per square foot. It has resulted in over 720,000 tonnes of wallboard being discarded in Canada annually (Marvin, 2000; New West Gypsum, 2003; WRAP, no date; Yost and Halstead, 1996). Most of this wallboard ends up in landfills and results in adverse environmental impacts through the release of hydrogen sulphide gas and the leaching of metallic sulphide into groundwater (Marvin, 2000; McCamely, 2004; Smith-Pursley, 1997). Faced with these findings, countries such as the United States and Canada have realized that alternative waste management options must be implemented (Recycling Council of Ontario, 2005).

Management options have been suggested and include:

1. Adoption of better waste minimization techniques to decrease the amount of wallboard waste created
2. Recycling this waste

However, getting these alternative options accepted poses a number of problems. These include: i) unwillingness by individuals in the industry to employ alternative disposal options; ii) economic barriers since better wallboard waste disposal options are more expensive than landfilling, given the low tipping fees; iii) increased transportation costs due to further distances being traveled for environmentally appropriate disposal; iv) and limited number of facilities that can properly handle clean and contaminated wallboard waste (Lingard et al, 2001; Recycling Council of Ontario, 2005; Saunders and Wynn, 2004). This is why 65% of clean and contaminated wallboard waste in Canada is discarded in landfills and why it is essential that an in-depth analysis be devoted to this issue. Realistic options need to be recommended so future wallboard waste can be handled in a more environmentally conscious manner, whether it is through greater recycling or the promotion of better reuse programs (Founie, 2007; Recycling Council of Ontario, 2005).

The goal of this research is to determine the most desirable and feasible options to deal with gypsum wallboard waste by understanding the overall lifecycle of wallboard and not just the disposal aspect of it. Wallboard management influences wallboard waste generation totals by the actions and behaviors employed. Being aware of this impact helps draw conclusions where improvements need to be made regarding the management of wallboard. Therefore, it is important to understand in this research, that gypsum wallboard management is incorporated under the broader category of gypsum wallboard waste management since every management action has a direct influence on the amount of wallboard waste being produced.

1.2 Purpose

The purpose of this study is to examine whether gypsum wallboard waste in Southern Ontario is being managed appropriately and if it is not being managed properly to determine the reasons why not and also determine what steps need to be taken in the future to resolve this situation. The aim of this research is to make realistic recommendations for managing gypsum wallboard waste based on the literature as well as beliefs of experts in the waste management field. The research question this thesis set out to answer is as follows:

What options are the most desirable and feasible to deal sustainably with gypsum wallboard waste in Southern Ontario now and in the future?

Six sub-questions have been addressed:

- How is gypsum wallboard managed in Southern Ontario?
- What set of criteria should be applied in efforts to design and develop sustainable IWM framework for managing gypsum wallboard?
- Are there any alternative wall materials that could feasibly replace gypsum wallboard?
- What are realistic options Southern Ontario could employ to manage clean and contaminated gypsum wallboard waste more sustainably?
- How do the recommended options, measure up to the developed sustainable IWM criteria set?
- What trade-off s can be made with the implementation of the recommended options?

1.3 Research Rationale

In 2005, a report published by the Recycling Council of Ontario identified one industry as failing to manage all of its waste appropriately. In this report, *Let's Climb Another Molehill*, 15 case studies were examined to understand why the construction industry was neither handling nor disposing its waste properly in Southern Ontario. These studies were employed to determine: 1) what the current situation was; 2) what types and quantities of waste were generated at project sites; 3) how was it being managed; 4) what were the barriers and opportunities to change current practices; and 5) how could this report get this industry to select options and design projects with the environment foremost in their mind. In its conclusion, generic recommendations were given to help improve the management of CRD waste (Recycling Council of Ontario, 2005). This study was the first of its kind done in Ontario. Although the report was substantial, the fact that it examined all major types of CRD waste made its focus too broad to allow for a detailed analysis of all waste streams and better waste management options. As a result, this report only offered general suggestions on what types of educational programs need to be developed, and how to better design and plan projects. While this report had three case studies dealing with gypsum wallboard waste, it did not provide specific waste management recommendations for each type of CRD waste.

Although it is not explicitly highlighted in the Recycling Council of Ontario recommendations the report did point out implicitly that gypsum wallboard waste is one material not being managed appropriately. In North America alone, 1% of the total waste stream's weight consists of clean and contaminated gypsum wallboard scraps (McCamely, 2004). The bulkiness of this material and the sheer quantity annually discarded not only consumes tremendous amounts of landfill space, but also has detrimental effects on the environment (Johnston, & Mincks, 1992; Marvin, 2000; McCamely, 2004; Smith-Pursley, 1997). Due in part to the limited regulations in Ontario regarding the disposal of clean wallboard waste (Ontario Regulation 103/94) and a lack of regulations concerning contaminated wallboard waste, the management of wallboard waste in this province consists mainly of dumping this waste in landfills. Development of alternative disposal practices is essential in improving the current situation (Environment Canada, 2003; Saotome, 2007). Limited knowledge on the part of many stakeholders regarding responsible management of wallboard has contributed to its continual inappropriate handling and disposal (Cochran & Beck, 2003; Smith-Pursley, 1997). The production of large quantities of natural and synthetic gypsum has kept manufacturing cost down, but at the expense of not promoting alternative disposal practices. This has unfortunately not been factored into wallboard cost. Low tipping fees (dollars per ton to unload the waste) and relatively high transportation costs to recycling facilities have been further economic factors that have influenced the management of this waste (Marvin, 2000; McCamely, 2004; Smith-Pursley, 1997).

The aim of this research is to narrow the scope of what was done in *Let's Climb Another Molehill* to one particular type of CRD waste, gypsum wallboard. By only examining one type of problematic CRD waste, the recommendations can be more specific to the situation. Making the context of the recommendations specific will lead to better management of this waste (Cochran and Beck, 2003; Laquatra, no date; Marvin, 2000; McCamley, 2004; Musick, 1992; Saotome, 2007).

1.4 Researcher's Perspective

The problems connected with gypsum wallboard management and disposal were first realized by the researcher when creating a national (United States) database for the construction industry. This database not only highlighted the different reuse and recycling facilities, but also identified what condition and types of construction waste these facilities were able to handle. After several months of working on this project at the Department of Environmental Protection in Boston, and after numerous discussions with waste processors in the Massachusetts area, it became apparent that gypsum wallboard waste not only being managed inappropriately, but the main disposal option available is to landfill the wallboard waste. This is the main reason why the researcher decided to focus this thesis on developing strategies that would sustainably improve wallboard management and its disposal techniques.

1.5 Study Area

Southern Ontario is the study site for the evaluation. This site spans from Windsor to Ottawa and from Lake Erie to Owen Sound. This area has been selected because of the 12 million individuals who inhabit Ontario approximately 80% live within this geographical boundary (Government of Ontario, 2006).

1.6 Target Audience

The target audience for this thesis includes public and private landfill operators, waste management coordinators, gypsum wallboard manufacturers, recycling facilities operators, construction industry managers, provincial policymakers, and environmental non-governmental organizations. These groups of individuals are chosen because they have the power to promote change. This research has also been written for the academic field since the amount of academic literature, which is devoted to wallboard management, is sparse.

1.7 Boundaries

1.7.1 Conceptual Boundary

This research only uses two core concepts, which are sustainability and IWM. Restricting research to two concepts can in some cases limit the scope. However, because sustainability is one of the concepts employed here, narrowness is not a problem. The fact that sustainability is extremely comprehensive in scope (Gibson et al, 2005) results in this conceptual framework not being inflexible and/or limiting. Furthermore, because IWM has been integrated within the sustainability concepts, it helps broaden the focus of the conceptual framework to include applications that center on waste management.

1.7.2 Temporal Boundary

Data (literature review, interviews, and observation sessions) were collected from January 2008 to April 2009. During this time, research was devoted to determine the management procedures used in dealing with the gypsum wallboard lifecycle, and its waste in Southern Ontario. Interviews and an analysis of the literature were also conducted to identify different wallboard management options that are available and also determine the feasibility of implementation. Because data collection was limited to fifteen months, it was restricted to what information was available during that timeframe.

1.7.3 General Boundary

This research has been restricted to gypsum wallboard waste and therefore other types of CRD waste have not been considered. The end goal is to recommend a list of feasible options for managing wallboard waste. It is assumed that many options recommended could be applied to other waste found within the construction industry.

1.7.4 Spatial Boundary

This study is interested in obtaining information about wallboard handling in Southern Ontario. The options recommended are designed in such a way that they could be adaptable to any part of Ontario or Canada.

1.8 Ethical Considerations

This research received ethics approval from the University of Waterloo's Office of Research Ethics since human interaction through interviews did occur. Receiving ethics approval ensured that any human interaction that transpired did not cause any physical, mental, and/or emotional harm to the participant.

1.9 Chapter Organization

This thesis is comprised of the nine following chapters:

1. Introduction – provides the background information and the justification for conducting this research.
2. Methodology – explains the step by step procedures used for each method.
3. Conceptual Framework and Criteria Creation – discusses the different concepts employed to create this framework and the sustainable IWM evaluation criteria set.

4. Construction Waste Management Issues – is a general discussion about CRD waste.
5. Gypsum Wallboard Waste Management Issues – is dedicated to gypsum wallboard and all of the management problems associated with it.
6. Assessment of Alternative Wall Materials – highlights other wall materials available and their potential for being used as a substitute for wallboard one day.
7. Current End-life Management of Wallboard in Southern Ontario – discusses what disposal options are being used in Southern Ontario to manage gypsum wallboard waste.
8. Discussion of Recommended Options and their Evaluation – provides not only a detailed discussion about alternative wall materials and behavioral changes recommended, but also evaluates these options using the sustainable IWM criteria sets. Information discussed within this chapter is based on what was learned in the literature review, observation sessions and interviews.
9. Recommendations and Conclusions – identifies all the wallboard management options that should be implemented. This chapter also provides a wrap up of what has been learned and where future research should be headed.

Chapter 2: Methodology

2.1 Inductive Reasoning and Exploratory Research

Inductive logic is the only research model used in this thesis. This model follows the ideology that intimate knowledge of a problem, in this case gypsum wallboard waste must be understood before any solution, and/or recommendations can be made (Leedy, 1993; Palys, 2003; Pelham and Blanton, 2003). A literature review, interviews, and observations were the qualitative methods employed to acquire this knowledge. The focus of these methods is to gain a greater understanding of the wallboard waste situation in order to offer feasible solutions to deal with its management (Leedy, 1993; Palys, 2003).

This research is considered exploratory because it is interested in gaining a better understanding of an issue; in this case gypsum wallboard. Exploratory research is typically executed in conjunction with inductive reasoning (Palys, 2003).

2.2 Methodological Framework

The purpose of this research is to determine what options are the most desirable and feasible to deal sustainably with gypsum wallboard waste in Southern Ontario both now and in the future. To answer this question, a number of actions and methods have been employed. This seven stage framework below (table 2.1) was created as a guide. With the addition of each stage comes a greater understanding of the situation.

Table 2.1 The methodological framework employed in answering the research question

Stages	Behavior/ Methods	Information Acquired
Stage 1: Identification of the problem	• Discussion with professors and waste professionals • Review of literature	• Research question/sub questions • Research objectives • Concepts
Stage 2: Creation of conceptual framework	• Look at Sustainability concepts and Integrated Waste Management (IWM) approaches	• Creation of sustainable IWM Criteria
Stage 3: Information acquisition regarding the current management and disposal practices employed for CRD materials	• Review of CRD literature • Review of waste management literature	• Background knowledge
Stage 4: Information acquisition regarding the current management and disposal practices employed for gypsum wallboard	• Review of gypsum wallboard literature	• Background knowledge
Stage 5: Identification of ways to improve the current situation	• Review of literature – looking at past construction waste that was problematic to manage • Interviews with architects, waste experts, and	• Development of alternative wallboard management options

	construction industry • Observations at waste management facilities	
Stage 6: Completion of testing the recommended options against the criteria sets	• Literature review (using the created sustainable IWM criteria sets) • Interviews • Observations	• Evaluation of recommended options
Stage 7: Summarization of results and feedback	• Written report	• Discussion and recommendations on which management options are feasible for implementation, time it will take, and what the trade-offs/drawbacks are • Expansion of the findings to other areas • Acknowledgement of where future research should be headed

2.3 Research Methods

In conducting any research, it is critical that a holistic approach is taken to answer the research question. For any research to be viewed as complete, various methods must be implemented that complement and test one another (Atkinson and Coffey, 2002, Modell, 2005). By employing a multi-method approach, one is able to achieve this goal (Babbie, 2002; Leedy, 1993; Palys, 2003; Yin, 2003). Using this approach ensures that the data collected are both reliable and valid (Atkinson and Coffey, 2002; Leedy, 1993; Modell, 2005). In terms of this thesis, the three methods employed are a literature review, direct observations, and interviews. These methods are qualitative in nature and offer different perspectives, knowledge, and suggestions about wallboard waste management.

2.4 Literature Review

2.4.1 Background

The purpose of a literature review is to evaluate and assess as much relevant academic literature (peer-reviewed journal articles) as possible. A solid foundation not only helps identify where information is lacking, but also highlights what methods are the most appropriate to answer the research question (Deakin University, 2006; Washington and Lee University, 2007). The rationale for a literature review is the solid foundation it provides to both the researcher and his/her reader. Having this background knowledge not only helps in the development of interview questions, but also assists in suggesting options (Booth et al, 2003; Washington and Lee University, 2007).

2.4.2 Applications to Research

The reliability of information conveyed in the literature is vital to the integrity of any research. Every attempt has been made to gather literature that came from primary and secondary sources. The importance of procuring information from these sources is in the reliability and validity of the information they provide. In instances where the topic is too specific, an evaluation tool has been employed to ensure accuracy of the information (Booth et al, 2003; Noble, 2004). For example, only a few peer-reviewed resources related to gypsum wallboard and composite paneling have been found. Consequently, the main resources available are internet sources. Because the internet has no assessment tool to evaluate content correctness, all internet sources have been screened. The CARS (credibility, accuracy, reasonableness, and support) criteria set has been used to assess the dependability of information[1]. This set of criteria helps the researcher become aware and identify key pieces of information that only reliable internet articles would have (Harris, 2007; Noble, 2004). Resources are only considered trustworthy if they satisfied at least two of the CARS criteria set (Harris, 2007). Even though the CARS criteria set has been criticized in the past because of "expert judgment" calls, the criteria set is still used because of the comprehensive checklist employed to evaluate each internet source (Noble, 2004).

The literature review has been broken down into three sections. The first review helps to create the sustainable integrated waste management (IWM) criteria. During this stage, literature pieces that center on IWM and sustainability have been used to construct the sustainable IWM criteria set. Fortunately, the constant use of theories and concepts within the academic field created a vast quantity of primary resources explicitly devoted to these ideas.

The second review was general and focuses on informing the reader about: 1) construction, renovation, and demolition (CRD) materials; 2) the current wallboard situation in Southern Ontario; 3) regulations; and 4) waste management issues and solutions. This review provides the researcher with the necessary information, which is needed to start thinking about better wallboard management options.

The third section of the literature review helps identify the most promising alternative wallboard management options. From this review, option lists have been created based on literature that centers on material changes and change in practices. The resources used here include interior design books and articles dealing with past problematic construction materials (wood, concrete, and metal). Evaluation of these wallboard management options have been accomplished by using sustainable IWM criteria created during the first stage of the literature review. This in-depth literature review gives new insight while at the same time

[1] For a detailed explanation of the different CARS criteria categories, see the glossary.

it brings the waste management community one step closer to recommending realistic solutions to solve the inappropriate management of this waste.

2.5 Direct Observations

2.5.1 Background

The purpose of direct observations is to observe what is taking place to determine whether the information collected corresponds to findings from other methods (Palys, 2003). The two main reasons why observations are selected is the lack of researcher interference and the researcher's ability to blend into the natural environment (Pelham and Blanton, 2003). The purpose of these sessions is to observe firsthand the waste management procedures that take place at different waste management facilities in Southern Ontario. Going to these waste facilities helps identify and understand the disposal techniques available for dealing with gypsum wallboard waste.

2.5.2 Applications to Research

Three different waste disposal locations were selected for direct observations. These locations were selected because of diverse disposal techniques they employ for managing wallboard waste. The first observation took place at the regional landfill site in the city of Waterloo, Ontario. The second one, at a waste management company that specialized in disposal of construction waste, located in Kitchener, Ontario. The last one, carried out in Oakville, Ontario, at a waste disposal facility that specifically caters to the collection and recycling of wallboard waste. During these observation sessions field notes were taken. The field notes were personal narratives made about the actions and behaviors witnessed. The information gathered helped the researcher not only to verify the current disposal procedure employed for wallboard waste, but also to highlight any difficulties that might arise if this waste were disposed of in a more environmentally friendly manner.

2.5.3 Observation Procedure

The companies contacted for participation are listed within the Waterloo *Workplace Waste Reduction and Recycling Directory* as facilities that accept wallboard waste (Region of

Waterloo, 2008). Two out of the three facilities are recognized as wallboard recyclers while the third facility focuses on landfilling. All three waste management facilities were contacted either by phone or by email. During the first contact, the purpose of the research was explained. Officials at all facilities contacted gave verbal consent to allow observation at their facility. The only stipulation made by all three was having an employee accompany the researcher during the observation. This employee escort was required due to liability concerns. Once participation approval was obtained, the day and time was discussed. Before the observation started, an information letter was given to the facility operator. At the end of the session a feedback letter was handed out. Most observation sessions lasted half an hour.

2.6 Semi-structured Open-ended Interviews

2.6.1 Background

The purpose of this method is to elicit personal opinions, attitudes, beliefs, and/or knowledge about a particular topic (Sproull, 1995). Although interviews and questionnaires share similar characteristics in terms of information acquired and the strengths and weaknesses of using each approach, interviews were chosen over questionnaires because of the ongoing personal contact that is involved. The restriction about what information can be acquired from questionnaires no matter what kind is employed (self-administered, group-administered, and mail-out) is the reason why this method was not used (Palys, 2003). Receiving only written responses results in the research being limited to what is stated on the paper. Consequently, when confusion arises and clarification or probing of a response is needed, a questionnaire is unable to meet these demands (Sproull, 1995).With interviews the question-and-answer dialogue that comprises this method eliminates this problem all together. The ability to ask follow-up questions on a particular response, and get clarification on any statements that are confusing, is why this method was selected over questionnaires (Booth et al, 2003; Palys, 2003).

Semi-structured open-ended interview is an interview style, in which the interviewer has a list of open-ended questions to ask the interviewee. As the interview carries on, the interviewer may abandon the prepared set of questions if interesting comments are made and further information is warranted. The goal with using this type of interview method is the personal relationship that develops between the interviewee and interviewer. Because of location issues, some interviews were conducted over the phone rather than face-to-face. Although telephone interviews do not elicit the same personal contact as face-to-face interviews, this was not seen as a problem since all questions asked by the researcher were answered by interviews that were completed over the telephone (Palys, 2003; Sproull, 1995).

2.6.2 Applications to Research

Key informant interviews were conducted with waste management experts, architects/architectural designers, general contractors, and a trade worker who specialized in drywall hanging. All individuals interviewed had knowledge in the areas of waste management, building design, and/or construction site management and operation. The purpose of these interviews not only was to acquire background information on the current situation, but also was to test the practicality of implementing alternative wallboard management options. Obtaining the opinions from waste experts as well as from people in the construction industry was extremely important in evaluating which management options would likely succeed if implemented in the future.

2.6.3 Interview Procedure

Before any interviews took place, four different sets of interview questions (architects/designers, waste management coordinators, wallboard hangers, and general contractors) were created (see Appendices A, B, C, D). The foci of these questions were to acquire background knowledge about the current situation; the interviewee's job responsibilities; the practicality of implementing alternative wallboard management procedures; as well as personal opinions about what needs to happen in the future to improve wallboard management. The four sets of interview questions had been pretested with four other individuals who all had waste management knowledge. Pretesting was done to determine whether any confusion or biases existed as well as to eliminate any questions that were not pertinent in answering the research question. Although there was a generic list of questions to ask, because these interviews were semi-structured, questions did differ slightly from one interview to the next. Interviewing three individuals from each question set was the intended goal. This target number was not achieved with wallboard hangers and general contractors due to unwillingness of the individuals in this industry to participate.

There were a number of actions taken to find the appropriate people to interview. The waste experts were selected because they either worked at a waste disposal facility that was part of the study area or their facility was identified in the Waterloo waste management directory as well as in the literature as being a leader in the management of wallboard waste. Five waste management facilities were contacted either by phone or by email. The purpose of this contact was twofold. First was to determine if the facility was interested in allowing one of their employees to be interviewed. Second was to obtain the name of an employee who was knowledgeable about the management of gypsum wallboard waste. Four out of the five facilities agreed to have an employee participate in an interview. The one facility that declined, explained that they no longer dealt with wallboard waste and therefore would be of no help. Once the researcher received participation approval, arrangements regarding the day, time, and place for interview were made.

Selection of architects interviewed for this research was solely based on recommendations given by a designer who worked for a large development firm. This individual felt that the architects he suggested were knowledgeable about building design and regulation, and would be excellent individuals to interview. The two architects recommended were contacted by phone and were both told the premise of this research and why their involvement was important. By the end of the conversation, the individuals agreed to take part in the interview. Once the researcher received participation approval, arrangements regarding the day, time, and place for interview were made. In the end, one architectural designer and two architects were interviewed.

General contractors and trade workers from accredited construction companies in the area were found through the Ontario General Contractors Association (OGCA). Most of the contractors found on the OGCA website focused on industrial and commercial projects. In deciding which companies to contact, factors such as location (Kitchener and Waterloo area) and contact information (website, phone number, e-mail address) played a role in the decision process. To find residential contractors and sub trades, the Waterloo Region Home Builders Association webpage was used. The factors of location and contact information were again used in deciding which residential contractors to contact.

Once the list was created, companies were contacted by email. After one week and no responses, the contractors and trade workers were re-contacted, but this time by phone. Messages were left with secretaries and on voicemail accounts. These messages explained the purpose of this research and asked companies whether they would be willing to participate. Three companies replied; however, only one was willing to be interviewed. Although this general contracting company agreed to an interview, the designer was the only individual allowed to be interviewed. Consequently, this interview was categorized under designer/architectural interview instead of a general contractor interview. Due to the very limited participation of this group of people, the contact pool was expanded. This expanded list included people recommended by interviewees as well as any trade worker and/or general contractors found in the Waterloo Region Home Builders Association. Once again, the same recruitment techniques were used. In total twenty-one general contractors and six trade workers were contacted. Out of the twenty-seven companies contacted, four immediately declined participation, three were willing (one residential contractor, one commercial/industrial/institutional contractor, and one trade worker) to participate, and the remaining twenty companies never responded. The four companies that did decline participation gave several reasons why they were not willing to take part. These included: liability issues, busy season, against company policy, and loss of man hours.

Before any interview began an information letter along with a consent form were given. Once the interviewee read over the letter and either signed or gave verbal consent, the interview began. Interviews ranged from fifteen minutes to one hour. At the conclusion of the interview, a feedback letter was either emailed or given to the individual. The letter thanked them for participating in the interview. A few days after the interview, a transcription of the interview was sent to each participant to ensure accuracy of the obtained information.

2.7 Benefits and Limitations with the Implementation of Each Method

Knowing the benefits and limitations of each method helps to develop strategies to combat any weakness that may appear. In the table below is a list of the most common advantages and disadvantages identified with using the three methods employed for this research.

Table 2.2 The method employed in this research and the benefits and limitations associated with their use

Method	Benefits	Limitations	Resource
Literature Review	• If article is peer reviewed the information has been rigorously assessed by peers in that field • A broad range of information can be retrieved in a relatively easy manner • Easy access to up-to-date literature • Broadens one's knowledge about a particular area • Helps the researcher establish the importance of the topic • Provides the reader with the background information needed to understand the research	• Not all sources are peer reviewed especially internet sources • Information can be out-dated particularly in fast changing fields • Time consuming • Literature can sometimes be extremely bias • Literature that is not peer reviewed can be inaccurate • Information can be difficult to retrieved due to privacy issues or cost	Palys, 2003 Pelham and Blanton, 2003 Sproull, 1995
Direct Observations	• Allows individuals to be observed in their natural environment • If done correctly individuals are unaware that observations are taking place	• Time consuming • If done wrong individuals are aware observations are taking place and may change their behaviors in order to satisfy the observer • Ethics problems in terms of privacy issues may arise	Palys, 2003 Sproull, 1995
Semi-structured Interviews	• Elicits personal information from an individual • Ensures the right person is interviewed • Can allow the research to explore why an individual may feel a certain way about a topic	• Extremely expensive because of the time required for each interview • The quantity of information gather is reduced due to time restraints • Interviewees may falsely inflate responses in order to please the interviewer (personal confound)	Palys, 2003 Pelham and Blanton, 2003 Sproull, 1995

• Interviewee is better able to articulated what exactly he/she means • Immediate clarification when confusion arises with regards to a question or response • Complex topics are more likely to be discussed and understood in the context of an interview	• Data may be inaccurate because the open-ended questions asked may be bias

Chapter 3: Conceptual Framework and Criteria Creation

3.1 Introduction

Various concepts were employed to understand the wallboard situation in Southern Ontario and what needs to happen to manage it better. The principles that underline each of these concepts in addition to the several methods employed were vital in creating the conceptual framework for analyses done in this thesis and in turn, the set of criteria to evaluate the feasibility and desirability of the various wallboard waste management options[2] (see Figure 3.1).

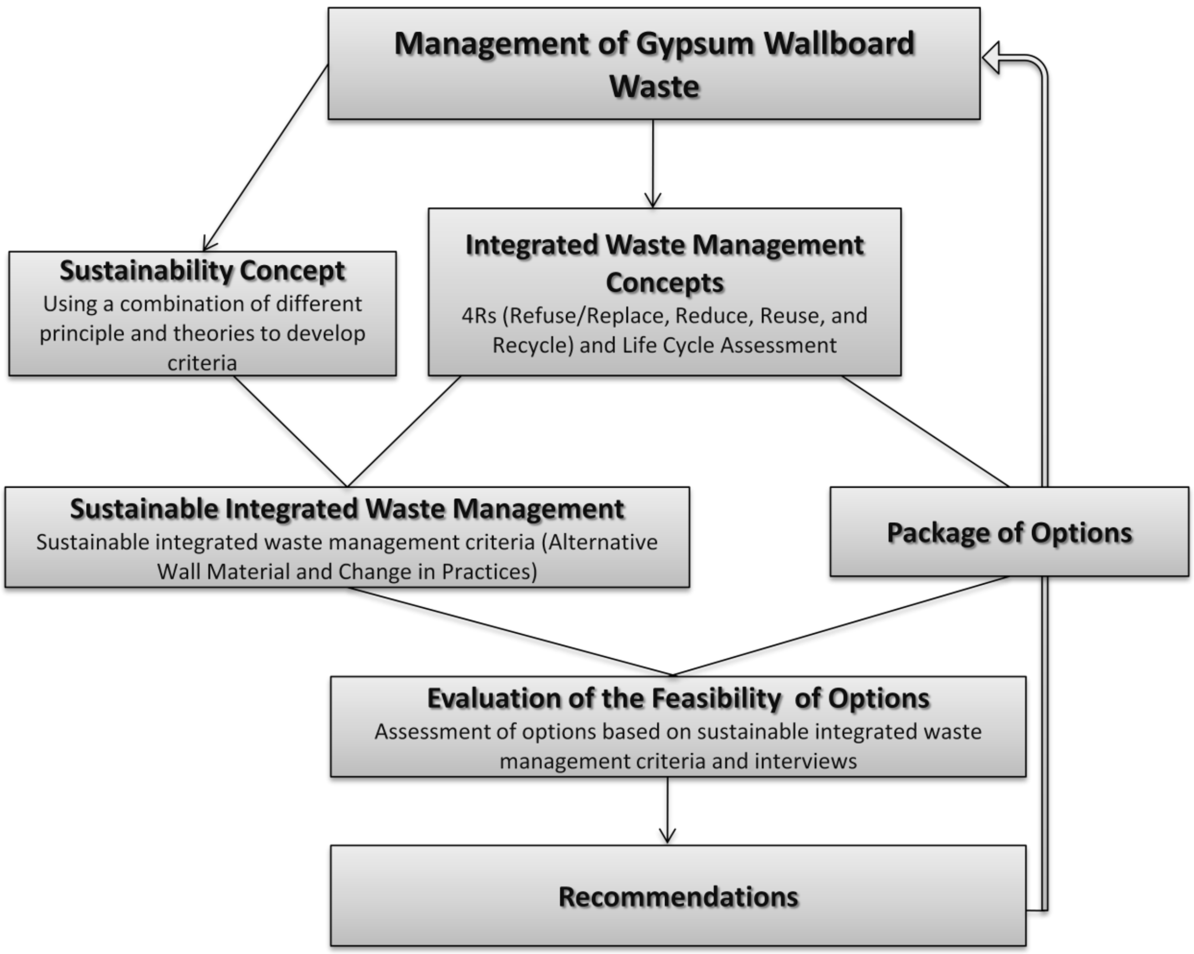

Figure 3.1 Framework for managing gypsum wallboard waste

[2] Discussion of the options and their evaluation can be seen in Chapter 8

Two concepts cited in the literature, which deal with waste management issues, are sustainability and integrated waste management (IWM) (Gertsakis and Lewis, 2003; Kharbanda, and Stallworthy, 1990; Klang et al, 2003; Seadon, 2006; Tchobanoglous, 2002). The similar but different complementary substance of these two concepts is why they have been selected. While both promote adopting a holistic approach to understand the issue, the actual evaluation of options is where their differences exist (Gibson et al, 2005; White et al, 1995). With IWM, assessment is based on the options' practicality while sustainability evaluates the options more theoretically (Gibson et al, 2005; Seadon, 2006). The different appraisal techniques have been consolidated into one framework – sustainable IWM – to gauge the feasibility of each option and to distinguish feasible and desirable management choices from less promising ones

This framework rests on the assumption that sustainability and IWM are the most practical concepts needed in developing the specific criteria for evaluating wallboard waste management options. For the broad purpose of finding better ways of dealing with gypsum wallboard waste, taking an integrated approach to analyze the problem is superior to an approach that is restricted to evaluating the situation from a narrower perspective like either economical or technical.

Sustainability and IWM not only complement one another by taking a holistic approach, but they also fill in assessment gaps where the other is lacking (Gibson et al, 2005; Seadon, 2006). More accurately, this research took the broad but also comprehensive concepts found within the sustainability framework and incorporated them into the IWM framework. The result of these actions is a consolidated sustainable IWM framework that is specifically designed for evaluating gypsum wallboard waste management options.

3.2 Sustainability

The term sustainability was introduced as a formal global objective in 1972 at the United Nations' Stockholm Conference on Human Environment (Gibson et al, 2005). During this time, the concept of sustainability was not widely accepted because of conflicting concerns about its implications. In 1987, the principles and ideals of sustainability were reintroduced in a report entitled *Our Common Future* released by the World Commission on

Environment and Development, which focused on sustainable development (Gertsakis and Lewis, 2003; Gibson et al, 2005; Klang et al, 2003). This report focused on the issues of human development and the environment. It argued that environmental degradation will continue to occur if human development and environmental protection are viewed as separate entities. It explained that sustainability can only be achieved if developmental needs, "allow people to sustain themselves while also sustaining the environment" (Gibson et al, 2005, pg. 48). Although sustainability was initially directed towards human development and the environment, it has expanded to encompass everything from sustainable performance assessments for businesses to sustainable waste management. Even with its implementation into different fields its focus has always remained the same, namely, development that does not comprise options for future generations (Beloff et al, 2004; Gibson et al, 2005; Klang et al, 2003).

Over the years, the concept of sustainability has endured a great deal of criticism from scholars and activists alike. Many of these individuals view its definition as being too weak and too contradictory. As a result, many alternative definitions have arisen and each of these definitions has taken a slightly different twist on sustainability's meaning. The progression of this concept has not only broadened its scope, but has also helped individuals take a more holistic viewpoint when analyzing a situation. It has caused individuals to show greater concern about the implications their actions have both now and in the future (Gibson et al, 2005).

In creating the evaluation criteria set, three different sustainability approaches have been selected – the pillar approach, Gibson's principles, and energy and material cycling. These approaches have been selected because each has been used in the past and has shown success in dealing with unsustainable problems. The integration of the three sustainability approaches ensures that an all-encompassing understanding of the wallboard situation has been gained.

3.2.1 Pillar Approach

The pillar approach has been employed because it promotes examining a problem from different established areas of concern and expertise including the ecological, social, and economical “pillars” (Gertsakis and Lewis, 2003; Gibson et al, 2005; Klang et al, 2003). The two key rules this approach follows are: 1) give equal attention to each pillar; and 2) identify where overlaps exist. If these two principles are followed, sustainability will be achieved (Gibson et al, 2005). This research follows the ideologies that encompass the interlocking circle approach.

The pillar approach is a favored sustainability approach because of its convenience. This approach allows any problem to be examined from traditional areas of expertise, which results in a readily available supply of information. Unfortunately only examining the problem from traditional fields of thought can lead to a restricted understanding of the situation and limit the ability to foster innovative thinking. A further problem is the weak integration of information among the pillars. Although this approach sees the pillars as being interconnected and interdependent with one another, the actual assimilation of information among them tends to be weak (Gibson et al, 2005). In using this approach, every attempt has been made to synthesize and integrate the information between each pillar to prevent this drawback from occurring.

3.2.2 Gibson’s Principles

Gibson’s eight principles of sustainability was another component used in the development of the assessment criteria framework. Although alternative sustainability principles exist, Gibson’s principles have been selected because they incorporate many of the sustainability arguments. Furthermore, they take an all encompassing approach in analyzing a situation. The eight principles for sustainable assessment include “socio-ecological system integrity, livelihood sufficiency and opportunity, intragenerational equity, intergenerational equity, resource maintenance and efficiency, socio-ecological civility and democratic governance, precaution and adaptation, and immediate and long-term integration” (Gibson et al, 2005, pgs. 116-118).

There are benefits and limitations in using any established principles. Strengths of Gibson’s principles cited in the literature include comprehensive scope, complexity of each category (which makes it difficult to fall into traditional sustainable categories), emphasis on principle integration (which leads to a more comprehensive understanding of the situation), and finally encouragement of actions that lead to sustainable development while at the same time not negatively impacting society or the ecosystem (Gibson et al, 2005). With these positives also come a number of problems. The first limitation is the unrealistic belief that there are always options that can lead to all positive outcomes. In most cases, any recommendations offered will involve trade-offs and sacrifices will be made for benefits to be experienced. The second drawback is the complexity associated with using these principles to make decisions or create options that will lead to sustainable action in the future. The last problem is the general nature of each category. The generic list of requirements presented by Gibson, unfortunately results in the principles not being case or context specific. Because of category looseness, particular attention must be devoted to each situation to ensure full understanding of the problem (Gibson et al, 2005). In order to avoid category looseness, sustainability principles in conjunction with IWM approach have been integrated together to evaluate the gypsum wallboard waste management options. Depicted in table 3.1 is a synthesis of the main requirements that each principle needs to consider in moving towards sustainability.

Table 3.1 Summary of the key requirement of Gibson et al. (2005) sustainability principles

Gibson's Eight Principles of Sustainability	Requirements
Socio-ecological system integrity	Ensure a long lasting relationship between humans and their ecological system in which threats and changes to desirable system qualities are at a minimum.
Livelihood sufficiency and opportunity	Ensure all individuals have an adequate standard of living and have the opportunity to improve themselves and their families without impeding the opportunities of future generations.
Intragenerational equity	Ensure the decisions and actions employed today will lessen the sufficiency and opportunity gap between rich and poor.
Intergenerational equity	Ensure the choices made today will not comprise future generation's ability to live sustainably.
Resource maintenance and efficiency	Ensure resource availability now and in the future by eliminating unsustainable practices, reducing actions that have damaging impacts on the environment, and avoiding wasteful practices that lead to unnecessary resource waste.
Socio-ecological civility and democratic governance	Ensure everyone is aware of the requirements of sustainability and get all individuals, communities, and decision-makers to apply these requirements in every action taken.
Precaution and adaptation	Ensure comprehensive understanding of the potential impacts that could result from each decision made. Where uncertainty does exist, favour options that will avoid or prevent damage.
Immediate and long-term integration	Ensure all principles are implemented at the same time, in ways that seek positive feedback for mutually reinforcing gains.

3.2.3 Energy and Material Recycling

The last sustainability concept employed centers on energy and material throughput and is based on the principles of efficiency, reuse and recycling. With this approach, attention is directed towards increasing the efficiency in the areas of material and energy usage, as a way to increase the sustainability of the action. An examination of both the production and consumption patterns helps to highlight where unsustainable behaviors lie and where changes can occur to make these products more sustainable (Gertsakis and Lewis, 2003).

One method that has proven to increase the efficiency of materials is the reuse/recycling of materials. This action mimics what transpires in the natural environment the constant cycling of materials throughout the entire system. It is the idea that nothing in the natural environment is viewed as waste – one species' waste becomes another species livelihood (Gertsakis and Lewis, 2003; Meadows et al, 1992). Improving the flow of energy and materials in a system involves reducing energy loss through the conversion of old materials into new products, decreasing the amount of waste discarded in landfills and increasing economic opportunities with the introduction of new products (Gertsakis and Lewis, 2003; Hawken et al, 1999). Improving energy and material flow should be a key in improving wallboard management.

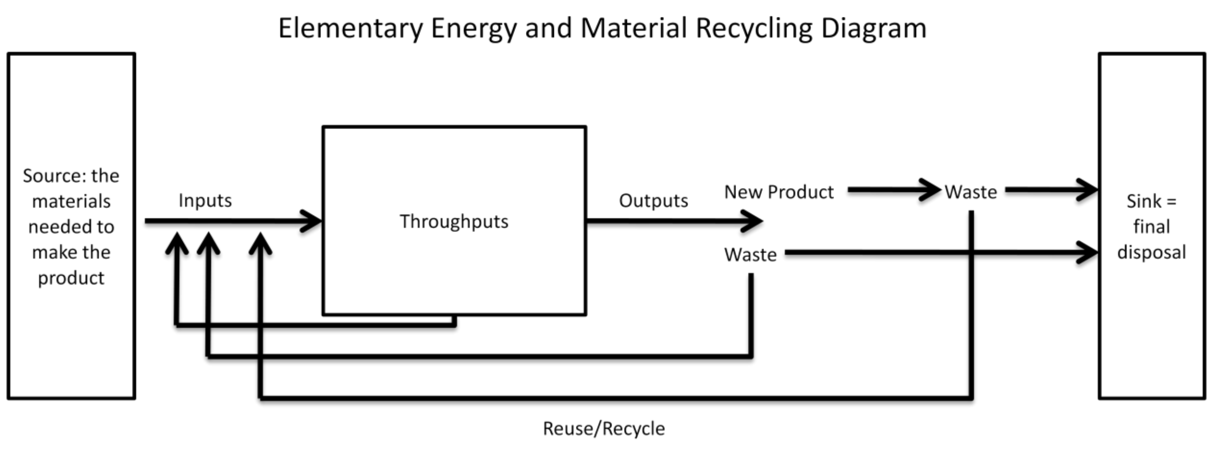

Figure 3.2 A diagram illustrate the principles that comprise the energy and material recycling concept

3.3 Integrated Waste Management

In 1996, The United Nations Environmental Programme defined IWM as, "a framework of reference for designing and implementing new waste management systems and for analyzing and optimizing existing systems" (Seadon, 2006 pg. 1328). The introduction of this concept encouraged individuals in the waste management field to take a holistic approach when it comes to examining a problematic waste management system. Acquiring a comprehensive understanding of the waste system is achieved by identifying the interrelationships that exist between the different components found within the system. The waste management hierarchy of refuse, reduce, reuse, and recycle is another component found within IWM. This hierarchy is used to identify what are the direct and indirect impacts associated with different disposal options. The long-term management approach IWM takes and the multiple perspectives employed provide a solid and reliable base for efficient waste handling and disposing. Because this concept uses existing waste management systems as well as designs and employs new options, it leads to better management of waste. The advantage of using an integrated system is waste is managed as an entire system from manufacturing all the way through final disposal (lifecycle), instead of many independent subsystems. It is easier to maintain, cheaper to run, and it does reduce environmental impacts. A limitation is the level of complexity that is involved in the development of an IWM approach (Seadon, 2006).

3.3.1 Waste Management Hierarchy

The waste management hierarchy in the order of priority is refuse (replace), reduce, reuse, and recycle. The aim of the hierarchy is to minimize the impact waste has on the environment (White et al, 1995). The hierarchy follows the idea that the most effective way to deal with a problem is to avoid it in the first place. Investing in options that reduce the overall amount of waste generated will decrease the amount of waste that will have to be managed in the future. For preventative approaches to have any success there has to be acceptance by affected stakeholders (Gertsakis and Lewis, 2003; Government of Canada, 2007). The waste management hierarchy principles employed in this research are the same as listed above. Although other waste management hierarchies exist, these four were selected because they are the most commonly cited and most often used in the waste management field (Government of Canada, 2007; Peng et al, 1995; White et al, 1995).

3.3.2 Lifecycle Assessment (LCA)

An LCA is viewed as an environmental management device that can be used by the waste management hierarchy to calculate the environmental impacts a product has from cradle to grave (Beloff et al, 2004; Bjorklund and Finnveden, 2005; Gertsakis and Lewis, 2003; Government of Canada, 2007; Milani, 2005). This approach examines each stage of a product's life to assess what its inputs and outputs are. Knowing this information allows one to predict what the overall adverse environmental impacts will be. If changes are made to the existing system, LCA can be used to calculate the effect of these changes. Incorporating a LCA with the IWM approach, ensures attention to the different impacts a product has throughout its life and provides a more comprehensive basis for determining which waste management options are best for the environment (Gertsakis and Lewis, 2003; Klang et al, 2003; White et al, 1995).

3.4 Criteria Development

The broad concepts of sustainability have been integrated with the IWM approach to create a sustainable IWM criteria set, which is case specific to this research. The steps taken to create the evaluation criteria involved examining the different sustainability concepts that apply to this research and tailoring them to the philosophies of IWM. Understanding and integrating these two concepts together was primarily based on information acquired through the literature review. Combining the sustainability concepts with IWM concepts involved highlighting both the common and uncommon themes found within each of these concepts, in order to come up with an all-encompassing criteria set that is able to take the underlying values of sustainability and apply them to the IWM framework (see table 3.2 and table 3.3). The goal of this framework is to design and implement better waste management techniques by understanding the lifecycle of a product, the role stakeholders play in the product's functioning, and the waste minimization techniques that can be utilized to improve the situation.

The creation of the criteria set was used to evaluate options that were based on the information witnessed from the observation sessions, responses obtained from the interviewees, and information acquired through the literature. All options recommended fit into one of two categories (alternative wall materials or change in practices). As a result, two sets of sustainable IWM criteria have been created. The main difference between these two criteria sets is whether the options being evaluated are a product or a behavior. The first set of criteria evaluates material options while the second set assesses options for changing industry/individual behaviors[3]. Both criteria sets integrate the sustainability concepts within the IWM framework. The only difference between the two criteria sets is the elimination of two evaluation items from the change in practices criteria. The two evaluation items eliminated are environmental impacts with anticipated improvements and material composition, as these two items are not applicable when rating a behavior.

The two criteria sets created are case specific. In other words, these criteria sets have been created for the sole purpose of evaluating management options that will improve the wallboard waste situation. Discussion about each item in the criteria set can be found in the sections entitled: *Sustainable IWM Criteria for Evaluating Alternative Materials* (see section 3.4.1) and *Sustainable IWM Criteria for Evaluating Change in Practices* (see section 3.4.2).

It should be noted that the criteria ratings given for the change in practice category is based on whether the behavior has been implemented. The change in practices options have been broken down into the following four subsections including the design phase, pre-construction phase, construction phase, and product specific phase. Item rating has been based on a positive (+) and negative (-) scale with neutral being equal to 0. The scale ranges from +,+,+ (extremely positive) to -,-,- (extremely negative). It should be noted that a rating of +,+ does not indicate that it is twice as positive as a + rating, but rather it indicates that this rating is just more positive. Discussion regarding what +/- represents in each criteria category can also be found in the sections entitled: *Sustainable IWM Criteria for Evaluating*

[3] Discussion about alternative materials and change in practices can be read in Chapter 8

Alternative Materials (see section 3.4.1) and *Sustainable IWM Criteria for Evaluating Change in Practices* (see section 3.4.2). Additional rating categories exist and include not applicable (N/A) and information not available (INA).

The purpose of creating these criteria sets has been to ensure evaluation consistency for each proposed option. Rating each option against the criteria set not only helps to highlight the positive and negative outcomes associated with each option, but it also assists in evaluating the feasibility of option implementation. The criteria ratings are based solely on the information acquired throughout the thesis process. Although the researcher will be the only one to evaluate each option the opinions and information gathered throughout the data collection stages will be used in assessing each option.

3.4.1 Sustainable IWM Criteria for Evaluating Alternative Materials

Depicted below is how the sustainability concepts were combined with IWM concepts to create the sustainable IWM criteria for evaluating alternative materials. In this section there is also discussion about each item within the criteria set and what a positive/negative rating indicates. Identifying what a positive/negative rating signifies for each evaluation item is based on data collected throughout this research (see chapter 5).

Table 3.2 Illustrates how sustainability principles were integrated with IWM considerations in order to create a set of sustainable IWM criteria for evaluating options for alternative materials

Sustainability	**IWM**	**Sustainable IWM Criteria for Evaluating Alternative Materials**
Pillar Approach		
Ecological	Examines a product's ecological impact from production to final disposal in order to make comprehensive decisions regarding the integrity of the environment	-Environmental Impacts with Current Techniques -Energy Consumption -Material Composition -Resource Availability -Travel Distance -Material Breakdown
Economical	Analyzes the economic cost a product carries throughout its entire life and the impacts it has on what route it should follow	-Travel Distance -Affordability -Employment
Social	Decisions which are based on the impacts a product has throughout its life and the role it plays on individual wellbeing, product appeal, and policy development/enforcement	-Health Impacts -Product Functionality -Product Rating -Product Availability -Stakeholders Attitudes -Education -Regulations -Enforcement -Stakeholder Participation -Service Availability
Gibson's Sustainability Principles		
Socio-ecological system integrity	Looks at the impacts a product has from cradle to grave in order to identify and improve any problems that lie within the system	-Environmental Impacts with Current Techniques -Environmental Impacts with Anticipated Improvements -System Vulnerability
Livelihood sufficiency and Opportunity	Extends resource availability (waste management hierarchy) by promoting waste minimization techniques to ensure future generations have the same opportunity and supply of resources available to make products	- Product Management

Intragenerational Equity*	Ensures stakeholders are well informed regarding decisions they make about a product. Looks at a product from cradle to grave and measures the impacts a product has on employment opportunity and job security	-Employment
Intergenerational Equity*	Examines the entire lifecycle of a product in order to highlight what actions lead to the least amount of adverse impacts on future generation when it comes to product production and disposal	-Future Considerations -Employment
Resource Maintenance and Efficiency	Takes a waste minimization approach when it comes to the lifecycle of a product in order to reduce energy and material inputs, minimize throughputs, and decrease waste outputs	- Environmental Impacts with Current Techniques -Energy Consumption - Product Management -Product Donation - Donation Restrictions
Socio-ecological Civility and Democratic Governance	Encourages stakeholders to openly participate with one another when it comes to decisions about a product as well as the rules and regulations governing the product throughout its lifecycle	-Regulations -Enforcement -Stakeholder Participation
Precaution and Adaption	Understands the entire lifecycle of product in order to identify uncertainties that may exist, which hinders the functioning of the entire system	-System Vulnerability -Product Uncertainty
Immediate and Long-term Integration	Is aware of all principles previously discussed and the need for them to be incorporated simultaneously with one another in order for the lifecycle of a product to function sustainably	-Holistic Understanding

Energy and Material Cycling		
Efficiency	Identifies where inefficiencies in material and energy usage exist and where changes need to occur in the lifecycle of a product	-Energy Consumption -Material Composition -Resource Availability -Travel Distance
Reuse	Extends the life of product by passing it on to others who see value in it	- Product Management -Product Donation -Donation Restrictions
Recycling	Focuses on redirecting materials away from final disposal by sending a product to facilities that can recover and reprocess the materials found within the product	- Product Management -Service Availability

* The issue of equity is covered by the employment category given that recommended wall materials and management options will not play a significant role in increasing housing prices

Environmental Impacts with Current Technique– environmental impacts (land, water, air, habitat disturbance and modification, species disturbance and biodiversity loss) that currently arise with the creation, use, and disposal of a particular product
+ = contributes to the functioning of ecological system
- = damages the natural functioning of the ecological system

Environmental Impacts with Anticipated Improvements – environmental impacts (land, water, air, habitat disturbance and modification, species disturbance and biodiversity loss) that will arise in the future with the creation, use, and disposal of a particular product
+ = contributes to the functioning of ecological system
- = damages the natural functioning of the ecological system

Health Impacts – impacts on human health that arise with the creation, use, and disposal of a particular product
0 = no anticipated health problems
- = development of health problems

Energy Consumption – the amount of renewable/nonrenewable energy resources relied on for product creation, use, and disposal
+ = renewable
- = nonrenewable

Material Composition – renewability of resources used to manufacture a product
+ = use of renewable resources
- = use of nonrenewable resources

Resource Availability – availability of resources being used to create a product
+ = infinite supply
- = limited supply

Travel Distance– the distance a product travels at different stages of its life- cradle to grave
+ = less than 30 kilometers traveled
- = over 30 kilometers (see section 5.4. 2 Transportation and Manufacturing Cost)

Product Functionality – durability, aesthetic appeal, maintenance ease, installation ease

- Durability
  + = difficult to break
  - = easy to damage
- Aesthetic appeal
  + = visually appealing to the eye (norm)
  - = visually unappealing to the eye (against the norm)
- Maintenance ease
  + = once installed can be left alone
  - = maintenance is required once installed
- Installation ease
  + = can do it yourself
  - = need of a professional installer

Product Rating – insulation, noise, fire, mold, and moisture resistant ratings of a product

- Insulation
  + = R-value of 40 or higher
  - = R-value below 40
- Noise
  + = 5/8 inch thickness
  - = 1/2 inch thickness
- Fire
  + = fire rating of at least one hour
  - = fire rating under one hour
- Mold
  + = mold resistant
  - = not mold resistant
- Moisture
  + = moisture resistant
  - = not moisture resistant

Product Availability – readily available supply of a product
+ = can buy at any building supply store/construction material depot
- = unavailable to purchase at local building supply store/construction material depot

Affordability – financial costs to purchase the product
+ = $10 or under per sheet
- = above $10 per sheet

Stakeholder Attitudes – acceptance by this industry to use a particular product
+ = always uses the product
- = rarely uses the product

Stakeholder Participation – stakeholders have an opportunity to provide suggestions and ideas throughout the life of a product
+ = open communication
- = a lack of communication

Education – stakeholders' knowledge when it comes to a product's installation and disposal
+ = implementation of proper product management techniques in order to produce the least amount of waste
- = lack of proper technique in place leading to unnecessary waste creation

Employment –individuals whose livelihoods are directly affected by the creation, use, and final disposal of a product
+ = leads to employment
- = leads to job loss

System Vulnerability – vulnerability of the system (see section 5.5)
+ = stable system
- = unstable system

Product Uncertainty – altering the natural state of a product
+ = no adding of man-made chemicals
- = adding of man-made chemicals

Regulations – regulations in place that deal with the disposal of a product
+ = there are regulations
- = there are no regulations

Enforcement – regulations being enforced by the government
+ = enforcement of regulation
- = no enforcement of regulations

Product Donation – a product can go for donation
+ = donated
- = not donated

Donation Restrictions– requirements that limit whether a product will be accepted for donation
+ = acceptance of a clean product
- = decline of a clean product

Service Availability – enough services such as recycling facilities and designated waste bins in the area to properly recycle a product
+ = there are services that can recycle the product
- = there are no services that can recycle the product

Material Breakdown – ability for the product to breakdown naturally
+ = decompose naturally
- = unable to decompose naturally

Product Management – are the waste minimization techniques of reduce, reuse, and recycle in place for a particular product (use and disposal)

- Reduce
  + = reduction strategies are in place
  - = no reduction strategies are in place
- Reuse
  + = reuse of existing material
  - = does not reuse existing material
- Recycle
  + = product is recycled
  - = product is not recycled

Future Consideration – the impact a product will have on future generations
0 = there is no further impacts from a product
- = there are increased impacts from a product

Holistic Understanding – awareness of all the interaction that take place with creation, use, disposal of product
+ = understanding of how the system operates
- = lack of understanding of how the system operates

3.4.2 Sustainable IWM Criteria for Evaluating Change in Practices

Depicted below is how the sustainability concepts were combined with IWM concepts to create the sustainable IWM criteria for evaluating change in practices. In this section there is also discussion about each item within the criteria set and what a positive/negative rating indicates. Identifying what a positive/negative rating signifies for each evaluation item is based on data collected throughout this research (see chapter 6).

Table 3.3 Illustrates how sustainability principles were integrated with IWM considerations in order to create a set of sustainable IWM criteria for evaluating options for change in practices

Sustainability	IWM	Sustainable IWM Criteria for Evaluating Change in Practices
Pillar Approach		
Ecological	Examines the impacts a behavior has on the ecological surroundings in order to make comprehensive decisions to ensure environmental integrity	-Environmental Impacts with Current Techniques -Energy Consumption -Resource Availability -Travel Distance -Material Breakdown
Economical	Analyzes the economic cost a behavior carries throughout its use and the impacts it plays	-Travel Distance -Affordability -Employment
Social	Decisions based on the impacts a behavior has and the role it plays in effecting individual wellbeing, product appeal, and policy development/enforcement	-Health Impacts -Product Functionality -Product Rating -Product Availability -Stakeholders Attitudes -Education -Regulations -Enforcement -Stakeholder Participation -Service Availability
Gibson's Sustainability Principles		
Socio-ecological system integrity	Looks at the impacts a behavior has throughout its use in order to identify any problems that may exist and improve upon it	-Environmental Impacts with Current Techniques -System Vulnerability
Livelihood sufficiency and Opportunity	Extends resource availability by promoting waste minimization techniques (reduce, reuse, and recycle) to ensure future generations have the same opportunity and supply of resources available to make products	- Product Management
Intragenerational Equity*	Examines how stakeholder wellbeing is influenced by the role a behavior has on employment opportunity and	-Employment

	job security	
Intergenerational Equity*	Examines the role a behavior plays on a product in order to highlight what aspects of that behavior lead to the least amount of adverse impacts on future generation when it comes to product production and disposal procedures	-Future Considerations -Employment
Resource Maintenance and Efficiency	Takes a waste minimization approach in order to reduce energy and material inputs, minimize throughputs, and decrease waste outputs	- Environmental Impacts with Current Techniques -Energy Consumption - Product Management -Product Donation - Donation Restrictions
Socio-ecological Civility and Democratic Governance	Encourages stakeholder participation in decision-making regarding a behavior as well as behavioral awareness about the rules and regulations that govern it	-Regulations -Enforcement -Stakeholder Participation
Precaution and Adaption	Understands how a behavior impacts the systems in order to identify where uncertainties exist which could hinder the functioning of the system	-System Vulnerability -Product Uncertainty
Immediate and Long-term Integration	Encourages all behaviors to simultaneously be incorporated together if sustainability is going to be achieved	-Holistic Understanding
Energy and Material Cycling		
Efficiency	Identifies behavior inefficiencies within the system in order to improve performance within that system	-Energy Consumption -Resource Availability -Travel Distance
Reuse	Encourages behavior that promote product extension	- Product Management -Product Donation -Donation Restrictions
Recycling	Focuses on behaviors that try to redirect materials away	- Product Management -Service Availability

	from final disposal in order to extend material life	

* The issue of equity is covered by the employment category given that wallboard will not play a significant role in increasing housing prices

Environmental Impacts with Current Technique– environmental impacts (land, water, air, habitat disturbance and modification, species disturbance and biodiversity loss) that currently arise with wallboard due to a particular behavior being implemented
+ = behavior contributes less damage to the functioning of ecological system compared to the current wallboard situation
0 = behavior contributes the same damage to the current functioning of the ecological system
- = behavior contributes more damage to the functioning of the ecological system compared to the current wallboard situation

Health Impacts – impacts on human health that arise with the implementation of a particular behavior
+ = behavior will lead to less health problems compared to the current wallboard situation
0 = behavior will lead to the same current health problems
- =behavior will lead to more health problems compared to current wallboard situation

Energy Consumption – the impact a behaviors has on the amount nonrenewable energy that is need for wallboard
+ = consumption of nonrenewable energy will be less compared to the current wallboard situation
0 = consumption of nonrenewable energy will be the same to the current wallboard situation
- = consumption of nonrenewable energy will be more compared to the current wallboard situation

Resource Availability – the impact a behavior has on the availability of resources being used to create wallboard
+ = the supply of gypsum mineral will be higher compared to the current wallboard situation
0 = the supply of gypsum mineral will be the same to the current wallboard situation
- = the supply of gypsum mineral will be less compared to the current wallboard situation

Travel Distance– the impact a behavior has on the distance wallboard travels
+ = overall travel distance will be less compared to the current wallboard situation
0 = overall travel distance will be the same to the current wallboard situation
- = overall travel distance will be more compared to the current wallboard

Product Functionality – durability, aesthetic appeal, maintenance ease, installation ease

- Durability
  + =breakability will be lower compared to current wallboard
  0 = breakability will be the same to current wallboard

- = breakability will be higher compared to current wallboard

- Aesthetic appeal
  + = the visually appeal will be higher compared to current wallboard
  0 = the visual appeal will be the same to current wallboard
  - = the visually appeal will be lower compared to current wallboard
- Maintenance ease
  + = maintenance will be easier compared to current wallboard
  0 = maintenance will be the same to current wallboard
  - = maintenance will be harder compared to current wallboard
- Installation ease
  + = installation will be easier compared to current wallboard
  0 = installation will be the same to current wallboard
  - = installation will be harder compared to current wallboard

Product Rating – insulation, noise, fire, mold, and moisture resistant ratings of a product

- Insulation
  + = insulation will be higher compared to current wallboard
  0 = insulation will be the same to current wallboard
  - = installation will be lower compared to current wallboard
- Noise
  + = noise level will be lower compared to current wallboard
  0 = noise level will be the same to current wallboard
  - = noise level will be higher compared to current wallboard
- Fire
  + = fire rating will be higher compared to current wallboard
  0 = fire rating will be the same to current wallboard
  - = fire rating will be lower compared to current wallboard
- Mold
  + = mold resistant rating will be higher compared to current wallboard
  0 = mold resistant rating will be the same to current wallboard
  - = mold resistant rating will be lower compared to current wallboard
- Moisture
  + = moisture resistant rating will be higher compared to current wallboard
  0 = moisture resistant rating will be the same to current wallboard
  - = moisture resistant rating will be lower compared to current wallboard

Product Availability – the impact a behavior has on where wallboard is sold
+ = behavior will increase where wallboard can be purchased
0 = behavior will have no impact in where wallboard can be purchased
- = behavior will decrease where wallboard can be purchased

Affordability – the impact a behavior will have on the financial costs to purchase wallboard
+ = behavior will decrease current purchasing price of a wallboard sheet

0 = behavior will cause no change in current purchasing price of a wallboard sheet
- = behavior will increase current purchasing price of a wallboard sheet

Stakeholder Attitudes – the feeling stakeholder's have towards a recommended behavior
+ = stakeholder's acceptance of the recommended behavior
0 = stakeholder's are currently using the behavior
- = stakeholder's rejection of the recommended behavior

Stakeholder Participation – the impact a behavior has on influencing stakeholder's ability to provide suggestions and ideas about wallboard
+ = behavior will promote more open communication compared to current situation
0 = behavior will promote the same communication to the current situation
- = behavior will not promote open communication compared to current situation

Education – the knowledge stakeholder's possess towards a particular behavior
+ = stakeholder's knowledge about the particular behavior is high
- = stakeholder's knowledge about the particular behavior is low

Employment – the impact a behavior has on individuals' livelihoods
+ = employment will be higher compared to current wallboard situation
0 = employment will be the same to current wallboard situation
- = employment will be lower compared to current wallboard situation

System Vulnerability – the impact a behavior has on the system (see section 6.4.6)
+ = behavior will improve the functioning of the wallboard system
0 = behavior will have no impact on the functioning of the wallboard system
- = behavior will decrease the functioning of the wallboard system

Product Uncertainty – the impact a behavior has on altering the natural state of wallboard
+ = behavior will cause the adding of chemicals to alter the natural state of wallboard
0 = behavior will not change the natural state of current wallboard

Regulations – is the recommended behavior being regulated
+ = behavior is regulated
- = behavior is not regulated

Enforcement – the impact a behavior has on wallboard regulations enforcement
+ = behavior is being enforced by a regulation
- = behavior is not being enforced by a regulation

Product Donation – the impact a behavior has on wallboard donation
+ = behavior will increase current wallboard donation levels
0 = behavior will lead to no change in current wallboard donation
- = behavior will decrease current wallboard donation levels

Donation Restrictions– the impact a behavior has on restricting wallboard from being accepted for donation
+ = behaviors will not influence the ability to donate wallboard
- = behavior will influence the ability to donate wallboard

Service Availability – the impact a behavior has in providing the necessary services such as recycling facilities, designated wallboard disposal bins, to recycle wallboard
+ = behavior will increase the numbers of services available compared to current situation
0 = behavior will have no impact on wallboard services
- = behavior will decrease the number of services available compared to current situation

Material Breakdown – the impact a behavior has on wallboard's ability to breakdown naturally
+ = behavior will increase wallboard's ability to breakdown compare to current situation
0 = behavior will have no impact on wallboard's ability to breakdown
- = behavior will decrease wallboard's ability to breakdown compare to current situation

Product Management – the impact a behavior has on encouraging waste minimization techniques of reduce, reuse, and recycle when it comes to wallboard use and disposal

- Reduce
  + = behavior will increase reduction strategies compared to current situation
  0 = behavior will have no impact on current wallboard reduction levels
  - = behavior will decrease reduction strategies compared to current situation
- Reuse
  + = behavior will increase reuse strategies compared to current situation
  0 = behavior will have no impact on current wallboard reuse levels
  - = behavior will decrease reuse strategies compared to current situation
- Recycle
  + = behavior will increase recycling compared to current situation
  0 = behavior will have no impact on current wallboard recycling levels
  - = behavior will decrease recycling compared to current situation

Future Consideration – the impact a behavior will have on future generations
+ = behavior will have a positive impact compared to current situation
0 = behavior will have no impact on wallboard's current situation
- = behavior will have a negative impact compared to current situation

Holistic Understanding – the impact a behavior has on providing awareness regarding the interaction that takes place within the wallboard system
+ = behavior will increase awareness of wallboard functioning compared to current situation
0 = behavior will have no impact on current wallboard functioning
- = behavior will decrease awareness of wallboard functioning compared to current situation

3.5 Summary

The first part of this chapter was devoted to the development of the conceptual framework. This framework relied on the concepts of sustainable and IWM to understand the wallboard situation in Southern Ontario and what needs to happen for it to be sustainably managed in the future. The second part of this chapter focused on these two concepts and their underlying principles, which played a vital role in creating the sustainable IWM criteria sets. The two criteria sets were created in the same way, taking the broad concepts of sustainability and integrating them with IWM. By combining the two concepts together two all-encompassing criteria sets were created that were able to assess the feasibility and desirability of recommendations that either centered on material or behavioral changes.

Chapter 4: Construction Waste Management Issues

4.1 Background

The first part of this chapter is dedicated to a review of literature that specifically focuses on construction, renovation, and demolition (CRD) waste management issues. This review has been done due to a lack of literature pertaining to the management of gypsum wallboard waste. An evaluation of this literature helped to identify actions that have been successful in improving the management of other problematic CRD waste.

4.2 CRD Waste Definition and Contents

The purpose of this research is to develop wallboard management options that could feasibly be implemented in Southern Ontario. This requires understanding the management of other CRD waste first. Background knowledge helped to highlight the problems and processes encountered when alternative disposal options are implemented. By broadening the scope to include all CRD waste, a better understanding of the potential difficulties that could arise with managing gypsum wallboard waste resulted.

4.2.1 Definition of C&D/CRD Waste

Defining construction and demolition (C&D) waste is a longstanding debate not only within the construction industry, but also within the provincial and federal governments (Recycling Council of Ontario, 2005; Smith-Pursley, 1997). The failure to have a universal definition for C&D waste explains why gaps in waste quantity data and governmental regulations exist (Recycling Council of Ontario, 2005). These slight nuances can be read in the following C&D definitions. For instance, the US Environmental Protection Agency defines C&D debris as:

> Waste material that is produced in the process of construction, renovation, or demolition of structures. Structures include buildings of all types (both residential and nonresidential) as well as roads and bridges. Components of C&D debris typically included concrete, asphalt, wood, metals, gypsum wallboard, and roofing. Land clearing debris, such as stumps, rock, and dirt, is also included in some state definitions of C&D debris (US EPA, 1998 pg. 7).

The state of Massachusetts defines it as follows:

> Building materials and rubble resulting from construction, remodeling, repair, or demolition of buildings, or pavements, roads or other structures. C/D debris includes' concrete, bricks, lumber, masonry, road paving materials, rebar, and plaster (Smith-Pursley, 1997, pg. 18).

The United Nations Environmental Programme (UNEP) offers this definition:

> Construction and demolition debris are generated regularly… as a result of new construction, demolition of old structures, and regular maintenance of buildings. These wastes contain cement, bricks, asphalt, wood, and other construction materials which are typically inert (UNEP, no date, pg. 1).

The waste management industry for Canada defines it as: "Waste materials from the construction and demolition of roads, bridges and buildings such as wood, gypsum and metal" (Statistics Canada, 2004, pg. 17).

The similarities and differences between each of these definitions, explains why confusion arises when one sets out to classify C&D waste. Depending on how broad or how specific the definition is, influences what type of debris comprises C&D waste and what its rate of disposal is (Recycling Council of Ontario, 2005). With no established definition for C&D waste in place, each US state and each Canadian province has a slightly different perspective and consequently, assessment totals for C&D waste generation have and will continue to vary (Jang, 2000; Recycling Council of Ontario, 2005; Smith-Pursley, 1997).

Although all previously noted definitions failed to mention this, it should be noted that C&D waste can also be generated from natural disasters such as tornados, floods, hurricanes, earthquakes, and so forth (Huang et al, 2002; Smith-Pursley, 1997). This waste can be in the form of a solid, a liquid, a gas, or a combination of all three (Yahya and Boussabaine, 2006). While this thesis is in no way interested in assessing waste options that are feasible for all C&D waste, it is concerned with obtaining a broader understanding of the waste situation in the construction industry. Background knowledge on how different types of C&D waste have been managed in the past is essential in understanding the current wallboard situation. For this research, C&D waste will be defined as: all waste material generated either from natural disasters or the construction, renovation, and/or demolition of manmade structures, which include and are not limited to building, bridges, and roads (Jang, 2000; Smith-Pursley, 1997; UNEP, no date; US EPA, 1998). This definition is based on a synthesis of existing viewpoints in the literature. Construction waste will be identified under the acronym of CRD waste instead of the typical C&D acronym.

4.2.2 Sources and Composition of CRD Waste

What sources contribute to the generation of CRD wastes is an important question to answer. The generation of CRD waste can result from a number of actions including: natural disasters, site clearing activities, and CRD projects (Jang, 2000). Typically, CRD waste is classified as coming from residential or non-residential projects. In terms of weight quantity totals, residential activities comprise 43% of CRD waste while the remaining 57% is from non-residential actions (Recycling Council of Ontario, 2005). With new construction, the waste generated is typically a mixture of either unused or damaged new materials and is viewed as clean and uncontaminated. Waste created at demolition sites is usually a mix of large building components such as wood and metal studs, bricks, concrete, and so forth and is seen as mixed and contaminated (paints and adhesives) (Jang, 2000; Lawson and Douglas, 2001). This difference in waste types and quantities influences how CRD waste is managed. CRD waste that is mixed will be more difficult to manage then uncontaminated source separated materials (Cooper, 1996; Lawson and Douglas, 2001).

Material usage is influenced by the native materials of the area as well as their availability. Therefore, the composition of CRD waste varies considerably depending on the local resources. For instance in the United Kingdom, wood waste comprises less than 10% of the total weight of CRD waste generated in that country, while in Portland Oregon 43% of CRD waste by weight consists of wood waste (Cooper, 1996).

Classifying waste by site activity is one way to easily identify what type of waste will be produced. “Site preparation, excavation, foundation work, framing, metal work, wiring, plumbing, insulation, paint, drywall, paint, exterior finishing, and roofing” (Yahya and Boussabaine, 2006, pg. 12), are all activities that generate different sources and quantities of waste. In the case of installing walls, the waste created includes wallboard off-cuts, cardboard boxes, and tape, while the waste produced with exterior finishing include wood, bricks, masonry, vinyl, and mortar (Yahya and Boussabaine, 2006). Therefore, the local resources of the area as well as site activities influence the composition of waste produced as well as the waste management options implemented (Cooper, 1996; Yahya and Boussabaine, 2006).

4.3 CRD Waste Situation

As the world's population continues to rise, the construction industry has been and will remain a key player in satisfying building needs (Horvath, 2004). Although this industry is experiencing a decline in the number of projects slated for development, increased public scrutiny is still being placed on them due to the adverse environmental impacts associated with some of their practices (Horvath, 2004; Recycling Council of Ontario, 2005). Cutthroat competition, rising material and tipping costs, meager profit margins, the introduction of new regulations and the adjustment of existing ones, have all been factors that have slowly pressured this industry to begin to change its practices (Dainty and Brooke, 2004; Horvath, 2004).

4.3.1 Best Estimates of CRD Waste Volume

One area where improvements have started to emerge is in the management of waste at project sites. The rationale for targeting the creation, handling, and disposal of waste is the sheer quantity of materials consumed by this industry. It has been calculated that the annual product weight used by this sector is greater than any other industry (Horvath, 2004; Yahya and Boussabaine, 2006). Although waste generation has been identified as an issue, the attention it deserves has been limited. Commonly cited reasons include an inability to calculate accurately CRD waste quantities due to data deficiencies and no universal standards for when waste generations totals should be assessed (Ekanayake and Ofori, 2000; Recycling Council of Ontario, 2005; Yost and Halstead, 1996). These two problems have lead to an industry, which lacks precise total weight data. This has in turn made this industry unaware of their waste problem. Public awareness along with the adverse environmental impacts directly linked to CRD waste creation, has forced them to take a closer look at their waste management practices (Horvath, 2004; Yahya and Boussabaine, 2006).

It is estimated that 30% of trucks delivering waste to landfills contain solid CRD waste (Lawson and Douglas, 2001). Approximately 11.2 million tonnes of solid CRD waste was produced in Canada, in 2005 alone (Recycling Council of Ontario, 2005). With only 12% of CRD waste being recycled in Ontario (Saotome, 2007) landfilling is the most common disposal choice (Cooper, 1996; Horvath, 2004; Jang, 2000; Peng et al, 1995; Recycling Council of Ontario, 2005; Yahya and Boussabaine, 2006). This landfilled waste not only occupies valuable space, but also releases both greenhouse gases (carbon dioxide and methane) as well as leachates (Jang, 2000; Yahya and Boussabaine, 2006).

4.3.2 Further Reasons why CRD Waste is Produced and why this Waste is Landfilled

To further understand this industry's reliance on landfills, attention first must be directed towards CRD creation. Commonly cited reasons include i) poor planning and design, ii) errors in ordering whether it be buying too much of a product or purchasing the wrong material, iii) specification changes, iv) material damage during transportation, v) material damage due to accidents, vi) custom design resulting in material off-cuts, and vii) inappropriate storage (Gavilan and Bernold, 1994; Ekanayake and Ofori, 2000; Recycling Council of Ontario, 2005; Yahya and Boussabaine, 2006). This list illustrates not only extremely wasteful practices, but also indicates a lack of site control by the construction industry. With limited controls in place, the weight and volume of waste generated at project sites is enormous (Yahya and Boussabaine, 2006). Landfilling is the favored disposal choice because it is considered the fastest and cheapest disposal method (Kharbanda and Stallworthy, 1990). Further reasons cited for this disposal choice include: 1) a false belief that tipping fees at recycling centers will be more expensive; 2) low cost of raw materials makes the manufacture of new products cheaper than if it was made from recycled materials; 3) recycling facilities are limited in number; 4) transportation costs will be higher because waste will have to travel further distances to be recycled; 5) waste that is recycled is usually considered low-grade quality and therefore not in high demand; 6) contaminated waste is more difficult to handle and to recycle;7) added time is needed to source separate materials; and 8) information and education regarding prevention measures and diversion programs for managing CRD waste is lacking. A heavy reliance on landfilling has unfortunately been at the cost of the environment (Cooper, 1996; Horvath, 2004; Jang, 2000; Lawson, and Douglas, 2001; Recycling Council of Ontario, 2005).

4.3.3 Recent Improvements in CRD Waste Practices

Some jurisdictions have taken the necessary steps to improve their waste practices recently. The gradual increase in landfill tipping fees and the introduction of stricter governmental regulations banning certain products (clean wood waste and metal) from entering landfills, has forced this industry to reconsider its waste practices (Laquatra, no date; McCamley, 2004, Peng et al, 1997; Recycling Council of Ontario, 2005). The introduction of waste prevention measures along with the waste management hierarchy of refuse, reduce, reuse, and recycle has dramatically shifted the management of construction waste in certain areas. Having this industry start to focus on eliminating the environmental damages connected with CRD waste and reducing unnecessary resource consumption has led to positive waste management practices (Peng et al, 1997). Even though this industry has taken strides to reduce and divert its waste, it has been restricted to areas where progressive waste management practices are encouraged and promoted. Furthermore, CRD recycling has been limited to only a handful of materials, which include asphalt concrete, steel, aluminum, and wood. Other types of CRD waste, such as gypsum wallboard, have not been as fortunate. Economic challenges along with difficulties obtaining and the processing equipment (shredders, grinders, and hoppers) needed to recycle this material, has resulted in the continual landfilling of this waste (Horvath, 2004).

4.4 Waste Management in Ontario

4.4.1 Factors Influencing the Disposal Options Employed by the Waste Management Industry

Two factors that have contributed to low landfill division rates in Ontario are limited regulations (see section 4.5) and minimal encouragement by governmental agencies to redirect waste into more appropriate streams (Recycling Council of Ontario, 2005; RIS International Ltd., 2005; Saotome, 2007). In the early 1990's the steps taken to reroute waste away from Ontario landfills involved the implementation of stricter regulations and increased tipping fees. However, these actions caused waste haulers to transport some Ontario waste to the United States. Shipping waste to the United States had huge implications on Ontario businesses that specialized in the recycling of waste. Because these low-cost alternatives were favored over more environmentally responsible options, diversion services collapse. Businesses that once focused on this type of service were now given two alternatives either go out of business or become a transfer station. Faced with limited opportunity to succeed in diverting Ontario waste, many of these businesses shifted their practices to offer such services as being transfer stations. Poor regulatory practices regarding the management of waste in Ontario and limited support to encourage better waste practices were responsible for this situation (RIS International, Ltd., 2005).

4.4.2 CRD Waste Diversion Rates

It was estimated by Statistics Canada that in 2002, 1.1 million tonnes of CRD waste were generated in the province of Ontario. Of this waste 145,000 tonnes were diverted away from landfills while the remaining 1 million tonnes were discarded in landfills. In Ontario, the CRD waste diversion rate was assessed at 12%. However, the Canadian Construction Association has argued that the rate of diversion for CRD waste is as high as 26% (RIS International Ltd., 2005). What these three diversion rate figures illustrate is data discrepancy and a lack of accurate monitoring of CRD waste in Ontario. Even with discrepancies, it is still obvious that the diversion rate for CRD waste is low even though many materials within this waste stream can be recycled, such as concrete, asphalt, metals, wood, and gypsum wallboard (Saotome, 2007). The same reasons previously cited (see section 4.3) can also be applied to the Ontario CRD waste situation. The option to transport waste to Michigan has unfortunately discouraged businesses and municipalities in this province from adopting more progressive waste management approaches (RIS International, Ltd., 2005).

4.5 Ontario Regulations Pertaining to CRD Waste

In the province of Ontario, CRD waste is regulated by provincial legislation and municipal by-laws. The two pieces of provincial legislation that govern the management of CRD waste include the Environmental Protection Act (EPA) and the Building Code Act

(BCA). There are six EPA regulations (Regulation 347: General – Waste Management Specific 3R's Regulations; Regulation 101/94 – Recycling and Composting of Municipal Waste; Regulation 102/94 – Waste Audit and Waste Reduction Work Plan; Regulation 103/94 – Industrial, Commercial and Institutional Source Separation Programs; Regulation 524/98: Certificates of Approval Exemptions – Air; and Regulation 337/98: Ambient Air Quality Criteria) (Recycling Council of Ontario, 2005). These regulations are enforced by the Ontario Ministry of the Environment (MOE). Of these six regulations, the 3R's regulations, specifically 102/94 and 103/94, have received and continue to receive the greatest attention (Public Works and Government Services Canada, 2000; Recycling Council of Ontario, 2005; RIS International Ltd., 2005; Saotome, 2007).

The BCA, which is enforced by the Ontario Ministry of Municipal Affairs and Housing, has one set of regulations: Regulation 403/97 Section 2 entitled General Requirements, which centers on the handling of CRD materials. This regulation lays out the conditions for which used and/or recycled materials can be utilized in the construction and/or renovation of projects (Recycling Council of Ontario, 2005).

In terms of provincial laws, waste reduction plans as well as waste audits have been key pieces of legislation that have resulted from the EPA and BCA acts. Municipal authorities have tended to focus on waste management practices and the implementation of by-laws to restrict certain types of waste from entering local landfills. By-laws created by municipalities are usually enacted where the municipality owns and/or operates the landfill. These waste restrictions are in place to help lessen the impact certain waste has on the environment and to try and extend the lifespan of the landfill (Public Works and Government Services Canada, 2000).

4.5.1 3R's Regulations

The EPA introduced the 3R's regulations in Ontario on March 3, 1994 to assist in the management of construction and demolition waste (Tanner, 1995). The 3Rs regulations established are 101/94, 102/94, and 103/94. However, the last two regulations of the 3Rs play the greatest role in CRD management. In terms of regulation 102/94, the "mandatory" requirements that must be completed before a project can be slated for development include

1) the execution of an on-site waste audit to classify the composition and quantity of waste being generated; 2) the creation of a waste reduction work plan that identifies certain reduce, reuse, and recycling options that are available and that can be taken to divert a project's waste away from landfills; 3) the actual execution of the work plan; 4) submission of records that document to the MOE the completion of the waste audit and the implementation of the work plan; and 5) ensure the audit and work plan information is saved by the construction company for the next five years. The provisions that have to be met by regulation 103/94 include 1) the establishment of source separation programs for waste classified under regulation 102/94 as being either reusable or recyclable; 2) the development of a facility list that identifies companies that are adequate in the collection, sorting, handling, and storage of diverted waste materials; and 3) the offering of educational programs to employees and customers alike to communicate the importance of source separating materials (Public Works and Government Services Canada, 2000). The construction materials regulation 103/94 requires recycling of includes the following items: cardboard, brick and concrete, unpainted drywall, steel, untreated wood while at demolition sites they are brick and concrete, unpainted drywall, steel, and untreated wood (Saotome, 2007).

The aim of these regulations was to minimize waste and to maximize diversion through the development of a waste diversion plan whereby all waste sources have to be properly separated so that it can be recycled. For the most part, these regulations have been viewed as weak and ineffective because of the limited enforcement directed towards them (Recycling Council of Ontario, 2005; RIS International Ltd., 2005; Saotome, 2007). With the initial implementation of these regulations in 1994, a number of companies were established to assist the construction industry in meeting these new requirements. These companies focused on providing services that involved the execution of waste audits and source separation programs. Furthermore, a number of transfer stations as well as recycling facilities were opened to meet the needs of the construction industry. All of these companies and programs were temporary due to the limited enforcement on the part of the MOE. Enforcement of these programs was terminated due to a reduction in MOE resources (RIS International Ltd., 2005). Between the years 2000-2001 the Environmental Commissioner of

Ontario highlighted the ineffectiveness of these regulations. The Commissioner's annual report discussed the lack of enforcement by MOE staff on the 3R's regulations. From this report, steps were taken to try and improve regulation monitoring. However, this regulatory enforcement was only short lived (RIS International Ltd., 2005; Saotome, 2007).

Additional problems cited with these regulations involve project size. Regulations 102/94 and 103/94 were established to apply only to projects that have a floor area of over 2,000 square meters (m^2). This specific size requirement dramatically reduces the number of projects that have to "abide" by these laws. Furthermore, a clause in Ontario Regulation 103/94 permits wallboard waste to be landfilled if it is contaminated. This loophole illustrates the ease, in which this industry can landfill its waste (Environment Canada, 2003; Ministry of the Environment, 1994; Recycling Council of Ontario, 2005; Saotome, 2007). Even with these three regulations in place, they have done little in getting the construction industry to change its disposal practices (Saotome, 2007). In its infancy, the 3R's regulations did encourage construction companies, landfill operators, and recycling industry, to start to revolutionize CRD waste management. However, these regulations were unable to be enforced for a long period of time and as a result they were pushed aside by the construction industry. Because this sector has never viewed these regulations as mandatory, since their initial creation and enactment, limited waste diversion programs have been implemented (RIS International Ltd., 2005).

4.6 Waste Management Options for CRD Waste

As previously stated, the construction industry is a major generator of and key contributor to the annual amount of solid waste discarded in private and public landfills (Poon et al, 2001;Yahya and Boussabaine, 2006). Because of the high diversion potential for a majority of this waste, various landfill reduction methods have been implemented and include better project design, waste minimization techniques of refuse, reduce, reuse, and recycle and source separation programs. Great strides have been taken with approaches geared towards waste reduction initiatives over the years. Unfortunately, these approaches are still not being used to their full potential (Cosper et al, 1993).

4.6.1 Project Design

If projects were designed with waste minimization techniques in mind, the materials used and the construction techniques employed would differ greatly compared to what is currently being done. Projects would be designed in such a way that they could easily be dismantled. If building disassembly was kept in mind, not only would this reduce the amount of waste being discarded, but many of the materials could then be salvaged and reused again. Today, most projects are neither designed nor constructed with this in mind. Any materials that are salvaged from demolition or renovations projects are typically so damaged that they are unable to be reused (Public Works and Government Services Canada, 2000). Therefore, greater attention and commitment need to be devoted to project development with specific focus directed towards structure disassembly. Disassembly approaches that do exist today include reversible connections instead of traditional screws and nails and the use of tongue and groove connections rather than adhesive compounds. Material selection is another critical step to help reduce a project's impact. Any products used on a project should have a lifespan rating greater than the structures expected life. Material selection based on this approach will prevent the need for renovation later on in the structure's life. Wear and tear problems will be reduced. Additionally, all materials used should either be reusable or recyclable products (Public Works and Government Services Canada, 2000). If these small steps were taken, one could witness a dramatic reduction in construction waste generation.

4.6.2 Waste Minimization: Reduce, Reuse, and Recycle

Most materials classified as waste at construction sites are not truly waste, but rather valuable resources that can either be reused or be broken down and remanufactured into new products (Public Works and Government Services Canada, 2000). The reality that most construction materials will continue to increase in price due to a constant decline in virgin materials should encourage the development and the implementation of alternative waste disposal options. These alternative options must employ disposal choices that are more environmentally responsible and also very progressive in terms of available waste minimization strategies. The waste minimization techniques must be designed to reduce CRD waste generation in the first place and any waste that is created should either be reused in other parts of the project or be donated to facilities, in which this so called waste can be used. This action will prevent it from being either landfilled or incinerated (Public Works and Government Services Canada, 2000; Tam and Tam, 2006). The goal of waste minimization is to lessen the amount of materials consumed in order to reduce the adverse impacts this waste will have on the environment. The philosophy is that fewer materials will lead to a reduction in waste generation (Peng et al, 1995).

4.6.2.1 Reduce

The concept of reduction centers on the idea the most effective way to minimize waste generation totals is to prevent its creation in the first place (Government of Canada, 2007; Peng et al, 1997). The only projects it can pertain to are construction and renovation jobs, where material purchase and usage occurs. Consequently, this reduction strategy is unable to be applied to demolition projects because no new products are being introduced (Public Works and Government Services Canada, 2000). The rationale to prevent waste generation from the start is to reduce the amount of waste that will have to be managed in the future (Government of Canada, 2007; Leverenz, 2002). The key strategies employed to apply this concept include the following:

- Product redesign –revamp products to increase lifespan so the product can be continuously reused and easily repaired
- Project design –order materials that correspond to the standard construction material dimensions
- Accountability of sub-contractors – ensures that the greater amount of waste produced by sub-contractors the smaller their profit margin
- Accuracy in ordering materials– order not only the correct products, but also eliminate over-ordering of the materials
- Product purchasing – purchase products that are known to be durable and long lasting
- Proper storage – store all materials properly during the construction stage to prevent material damage due to the outside weather elements

- Up-to-date inventory – keep accurate inventory information that highlights what and how much extra materials are leftover in order to make the correct adjustments during the next project (Cosper et al, 1993; Dainty and Brooke, 2004; Leverenz, 2002; Public Works and Government Services Canada, 2000; Recycling Council of Ontario, 2005).

The implementation of these waste prevention strategies will lead to successful decreases in the amount of waste generated at project sites, which is the overall goal of this concept (Public Works and Government Services Canada, 2000).

4.6.2.2 Reuse

Reuse means the movement of materials from one application to another and is the most attractive option after reduce. This waste management approach is favored highly due to the minimal amount of energy and material processing required (Leverenz, 2002; Peng et al, 1997). In construction related work, product reuse can be employed in any type of project as long as enough attention is given to its planning. Depending on the project type and whether it is designed appropriately, influences the amount of materials that can be salvaged for reuse (Public Works and Government Services Canada, 2000). The highest product recovery comes from demolition projects and if enough time and planning are devoted to the deconstruction of a building, enormous volumes of usable products can be reclaimed. Since deconstruction is time consuming and the materials that are salvaged are relatively inexpensive, little effort is given to this waste minimization technique unless the materials are worth money (such as cooper or rare woods). The most favored demolition approach is building destruction since it is the cheapest and fastest option. Minimal material recovery is possible because the activities employed lead to material damage. Most of the materials collected are either recycled or landfilled/incinerated. With each of these disposal options, added energy and processing is needed that otherwise would not have been required if the materials had been reused in the first place (Leverenz, 2002; Public Works and Government Services Canada, 2000). The various options available for reused materials include: drop and swap stations, salvage yards, local material exchange centers, and charitable donation businesses such as the Habitat for Humanity resale stores (Public Works and Government Services Canada, 2000). Product reuse is just another available tool in the CRD waste minimization toolbox.

4.6.2.3 Recycle

Recycling involves the reprocessing of a material by extracting as much usable resources from this waste as possible. It is about making new products out of materials once viewed as waste. With this waste minimization approach, it prevents the final disposal of usable resources by breaking down the waste. Through this process, raw materials that once comprised this waste are returned back to the market for reprocessing (Peng et al, 1997; Tchobanoglous et al, 2002). Even though recycling requires the input of energy, in terms of material reprocessing and remanufacturing, this waste management approach is preferred over other disposal choices due to a number of reasons. The benefits of this action include that finite resources are saved; that a reduction occurs in the amount of virgin materials that need to be mined; and finally that it is able to capture usable resources that would have otherwise been lost (Tchobanoglous et al, 2002).

When CRD materials are recycled, they are usually hand sorted from other CRD waste. Once the recycled materials have been removed, they are brought to a recycling facility. At the facility, a variety of machines are used to process the waste to not only reduce the size of the material, but also to remove any impurities that exist. If impurities such as nails in wood and tape on gypsum wallboard are not removed, it hinders the recyclability of the product. The typical CRD operations that are involved include crushing, grinding, pulverizing, and screening of the material. Material recycling is an exhaustive process because the resources that are collected must not only be of high quality, but must also be relatively clean. It is vital that recycling facilities operate properly to ensure that the greatest amount of resource recovery is accomplished (Tchobanoglous, 2002). In order for CRD materials to be recycled, proper source separation programs must be in place. The following section is a detailed discussion about the source separation approaches available.

4.6.3 Source Separation

Source separation of CRD waste is one method that has proven valuable to alleviate some of the landfill shortage pressure that currently confronts the waste management field (Poon et al, 2001). In the past, this waste approach was not well received by the construction industry on the belief that added labor costs would incur due to extra time needed to separate the materials into their appropriate diversion streams (Cosper et al, 1993; Poon et al, 2001). The need for added waste containers on-site was also an issue. Finally there would be an increase in waste disposal fees since some of the CRD waste would be diverted to recycling facilities instead of landfills (Cosper et al, 1993; Recycling Council of Ontario, 2005). However, time has brought improvements with this approach and it has shown that no added cost or labor time is required. Furthermore, the need for extra roll-off containers on-site will depend on what source separation approach is employed. For the most part, no added disposal fees will be incurred since recycling center tipping fees have decreased while landfill disposal fees have increased (Cosper et al, 1993; Smith-Pursley, 1997; Recycling Council of Ontario, 2005).

4.6.3.1 <u>The Difficulty in Implementing Source Separation Program On-site</u>

One of the most influential factors as to why source separation in Ontario has not gained either the attention or acceptance it deserves, deals with individuals who are responsible for on-site waste management. When a project is slated for construction or renovation, contracts are created and signed between the site manager and all involved sub-contractors. Typically, as part of the contract, the handling and disposal of waste is the responsibility of the sub-contractors; however, this is not always the case. Therefore, the issue of on-site accountability for waste management rests with every sub-contractor involved in the project (Recycling Council of Ontario, 2005). Because waste management is usually not controlled by a single individual, but rather by a number of individuals, it often results in the implementation of disposal choices that are the easiest and quickest. Rarely is thought and concern given to the environmental impacts this waste will have on land, water, and air. Nor is any consideration devoted to the added resources that will be extracted for each recycled material that is landfilled (Poon et al, 2001). Because there is no incentive for site managers either to encourage or to require CRD waste to be diverted, these inappropriate waste disposal practices will continue to occur. The ability to get sub-contractors to collectively come to together and agree to source separate their waste is unlikely since this action could benefit some while at the same time be a detriment to others (Recycling Council of Ontario, 2005).

4.6.3.2 Most Common Source Separation Approaches Available

The most common source separation approaches available to CRD waste generators are on-site source separation, on-site source separation based on job progression, off-site source separation by waste hauler, and off-site source separation by recycling facility (Smith-Pursley, 1997). In terms of on-site source separation, site managers select a particular number of products that are generated in high volumes and that can be diverted away from landfills. This selected waste can no longer be disposed in the designated landfill containers, but rather must be redirected to specialized containers where the waste will be transported to the appropriate recycling facilities. With this approach, site workers are required to participate in the sorting of recyclables from other landfill materials (Poon et al, 2001; Smith-Pursley, 1997). The other on-site source separation method involves the diversion of materials according to job progression. What this means is the diversion of one particular material at one specific phase of the project. For instance, if a new home is being constructed and the project is at the framing stage, the only waste collected for recycling is wood. Once the house is framed, a new stage of the project begins with a different type of waste selected for landfill diversion (Smith-Pursley, 1997). The two off-site source separation approaches are extremely similar in practice. Both options involve the disposal of CRD waste into generic roll-off containers and both require no additional labor to dispose the material (Poon et al, 2001). Depending on what off-site approach is employed, influences who services the waste- a recycling facility or a waste hauler. Once the waste is collected by either the waste hauler or recycler, the mixed CRD waste is then separated between recyclables versus garbage. If off-site separation is collected by a recycling facility, the recycled materials that are salvaged can be processed on-site while all garbage collected is transported to a nearby landfill. When CRD waste is collected by a waste hauler, not only is the materials separated off-site, but also the waste hauler has to transport all recyclables to various facilities and then haul all remaining garbage to the landfill (Smith-Pursley, 1997).

The most favored source separation approach used by the construction industry is the off-site waste management approaches. These off-site methods are highly appealing because on-site workers are not needed to source separate the materials (Poon et al, 2001; Smith-Pursley, 1997). This means that no additional time is required for waste disposal since all materials can be thrown into the same containers. The main reason why off-site separation is the preferred diversion approach is based on its convenience. With regards to the two on-site source collection methods, on-site source separation based on job progression is viewed by the construction industry as being the more attractive choice out of the two (Smith-Pursley, 1997). Consequently, the least favored approach is on-site source separation. With this approach, site workers not only take added time to sort the materials, but they must also participate in the unloading of this waste into the appropriate containers. The necessity to have additional waste containers along with extra time needed to dispose of the waste represents two reasons why this approach is the least favored.

4.6.3.3 Barriers Preventing Source Separation from being Implemented on Project Sites

The various source separation methods have all been successful in diverting CRD waste from landfills (Poon et al, 2001). The question then becomes – why are these approaches not mandatory waste management requirements? Reasons why source separation programs are not used include 1) limited provincial monitoring and regulations regarding waste management of CRD waste; 2) contamination of recyclable waste which makes once nonhazardous materials now hazardous (lead paint on drywall); 3) on and off-site separation problems; 4) insufficient education among construction workers regarding proper material separation and recovery; 5) added transportation costs of recycled materials due to further distances needing to be travelled; and 6) continuous market fluctuation in the value of recyclable materials (Cochran and Beck, 2003; Poon et al, 2001; Smith-Pursley, 1997; Recycling Council of Ontario, 2005). The construction industry must change radically, if source separation is ever going to be used to its full potential. This change must come in the form of i) awareness and consideration about the environmental impacts of one's action; ii) better employee education; iii) improved site control and management by the project leader; and iv) better planning and implementation of source separation programs (Poon et al, 2001).

4.6.4 Final Disposal Options

In managing CRD waste, every attempt should be made to lessen the total amount of waste going for final disposal either through the implementation of various waste reduction strategies or through material reuse and recovery options (Dijkgraaf and Vollebergh, 2004). Any remaining waste that is unable to be diverted faces two choices, which are either incinerate or landfill it. There are not only high environmental impacts associated with both of these disposal options, but also permanent loss of raw materials (Peng et al, 1995). The following section discusses both of these final disposal options in order to understand the benefits and limitations with each.

4.6.4.1 Incineration

Incineration is the process of waste reduction through combustion. With this disposal option energy can be extracted through the burning of waste. It should be noted, energy can only be extracted if the facility has the technology to do so (Brunner, 2002; Dijkgraaf and Vollebergh, 2004; Morris, 1996). The benefits with incineration include 1) removal and capture of energy from waste; 2) dramatic and immediate reduction in waste volume; 3) reduce environmental impacts when the correct technologies and controls are in place; 4) creation of ash which is converted to a viable by-products including landfill cover and creation of pavement; 5) disposal of a variety of waste forms (solid, paste, sludge, slurry, liquid, and gas); and 6) minimal amount of space needed for plant construction and operation (Brunner, 2002; Kharbanda and Stallworthy, 1990; Peng et al, 1995). Even with these benefits, a range of problems exist. These include high capital cost, need for skilled operators, creation of toxic by-products, constant loss of resource and the embodied energy found within it, as well as restrictions as to what waste can be incinerated (Brunner, 2002; Dijkgraaf and Vollebergh, 2004; GAIA, 2008; Kharbanda and Stallworthy, 1990; Milani, 2005). Even with proper controls in place, the release of various acidic gases still occurs and includes hydrogen chloride and sulfur dioxide. Other materials released are heavy metals that include cadmium, dioxins, and particulates (GAIA, 2008; Dijkgraaf and Vollebergh, 2004; Peng et al, 1995). Therefore, the type of incinerators used not only influences what type of waste can be burned, but also plays a role in the amount and type of emissions released (Brunner, 2002).

The role incineration plays with CRD waste is for the most part restricted. CRD waste is extremely difficult to incinerate because of the various materials that comprise it. The fact that soils and metals are some of the disposal materials that must be dealt with makes incineration of CRD waste an unfeasible option. Therefore, when mixed containers of CRD waste are ready for final disposal, they are not brought to incineration facilities, but rather to landfills. In instances where CRD waste can be separated between burnable and nonburnable items, only then is it a viable disposal option (Brunner, 2002).

4.6.4.2 Landfill

Landfilling waste is not only the oldest waste disposal method, but it is also the most commonly employed waste management approach. This disposal option involves the discarding of solid waste onto the surface soils of the earth (Kharbanda and Stallworthy, 1990; O'Leary and Tchnobanoglous, 2002). Landfilling is favored over alternative waste disposal options, such as ocean dumping and/or incineration because of the wide assortment of waste that can be accepted, the simplicity in landfill design and construction, and finally is the inexpensiveness associated with facility construction (Cheremisinoff, 2003; Kharbanda and Stallworthy, 1990; White et al, 1995).

Even though landfilling may be publicly the most acceptable disposal method, there are a number of drawbacks. Landfilling has been identified as having the highest environmental impacts compared to any other waste disposal option. These problems include the release of various gases into the atmosphere such as methane and carbon dioxide (CO2), the contamination of soil and groundwater, and the occupation of valuable land space (Cheremisinoff, 2003; Dijkgraaf and Vollebergh, 2004; Peng et al, 1995). Second is the noise and odor pollution that is created. Especially bothersome is the unsightliness of waste being dumped onto the earth's surface and the constant blowing of litter on nearby properties

(Cheremisinoff, 2003; White et al, 1995). Third is the inability to immediately reduce the volume of waste discarded. Landfilling is viewed as only a temporary waste management solution. Once it closes, not only is this land unable to be reused again for waste dumping, but it is limited in what types of activities and construction can be executed on it. This disposal approach is unable to solve society's waste problems since the only progressive waste management solution it follows is to close one landfill in order to open another (Cheremisinoff, 2003; White et al, 1995). Fourth is the difficulty in finding a suitable site for development (White et al, 1995). A final obstacle is the low collection and conversion of waste gases, specifically methane, into energy that is able to be secured (Cheremisinoff, 2003). Because landfilling is the preferred disposal choice, minimal attention or encouragement is given to the implementation of alternative waste disposal options. Therefore, every attempt should be made to only use this approach when all other disposal methods have been exhausted (Peng et al, 1995).

Over the years, great strides have been made from the once unlined open pit holes of the past to today's state of the art landfill facilities that use the newest types of technologies and preventative measures that are available to minimize any detrimental environmental impacts that may arise. These measures include lining impermeable layers of clay or rubber underground to prevent groundwater penetration and contamination, and on-site collection and treatment of leachate and gas. These measures have been created to lessen the environmental impacts associated with landfilling waste (White et al, 1995).

The type of waste being discarded influences the class of landfill the waste can be brought to. The various landfills that exist were designed and developed to specialize in the handling and management of different types of waste. The most common landfill categories are class I – hazardous waste, class II – designated waste, and class III – municipal solid waste (MSW). With each of these landfill types, different design requirements and regulatory conditions must be met and followed (O'Leary, and Tchobanoglous, 2002). CRD waste is disposed of in either a class II or III landfill. In the United States, in 2002, it was calculated that between 35 to 45 percent of CRD waste was discarded in designated C&D landfills while an additional 20 to 40 percent of this waste was thrown away in municipal landfill facilities. The problem with having this waste discarded in different landfill classes is the varying degrees of environmental prevention and protection. In cases where CRD waste is brought to designated C&D waste facilities, the regulations tend to be less stringent than at MSW landfills. These requirements are weaker based on the false belief that all CRD debris is inert and as a result will not release any toxic substances (Tchnobanoglous, 2002). Therefore, stricter regulations are needed for designated C&D landfills and even greater attention must be given to the condition of the landfill to prevent the release of any toxic gases.

4.7 Summary

Construction waste has played and will continue to play a significant role within the waste management field. The variety of debris that comprise CRD waste and the sheer volume that is annually discarded are why progressive waste management approaches must be both encouraged and implemented. Although steps have been taken to improve the management of this waste, especially through the adoption of better source reduction approaches and the implementation of reuse and recycle programs, further actions are still required. Additional steps are needed since these waste improvements have only been directed towards certain types of CRD debris. A further problem highlighted is the limited regulations that are in place and their lack of enforcement by government officials. Stricter disposal regulations are needed if CRD waste is to be handled more effectively in the future. Furthermore, a shared sense of responsibility is needed among all stakeholders with regards to CRD waste management. The current disconnect that exists between contractors and sub-contractors and the presence of weak regulations help to explain why landfill dumping is continually favored and used over other management alternatives. Unfortunately, with landfill disposal come a number of adverse impacts, which include:

- Occupation of valuable land, continuous habitat modification and biodiversity loss due to changes in the natural ecosystem resulting from landfill construction and use
- Constant release of greenhouse gases and the contamination of both soil and groundwater

- Absence of a long-term waste management option because landfilling only involves the storage of waste
- Permanent loss of raw materials due to the landfilling of the waste

The various waste management options that are available today from reduce/reuse to recycle are more sustainable and better for the environment must be implemented. An in-depth understanding of the current challenges facing CRD waste management combined with the potential problems that could arise if different options are employed helps to differentiate between successful versus unsuccessful approaches. Table 4.1 summarizes the various issues that currently influence CRD waste management. All of the challenges highlighted in the chart are all issues considered and addressed in developing feasible management options for wallboard waste.

Table 4.1 Summary of key issues influencing CRD management (Cooper, 1996; Horvath, 2004; Lawson, and Douglas, 2001; Leverenz, 2002; Recycling Council of Ontario, 2005; Saotome, 2007; Smith-Pursley, 1997)

Causes of CRD Waste Issues	Results from these Issues
1. Poor Information about the Volume and Characteristics of CRD Waste • No universal CRD waste definition	1. Confusion regarding what debris comprises CRD waste 2. Variation in CRD waste definitions amongst each region, which results in unreliable provincial CRD waste totals
• Inaccurate CRD waste total estimations	1. Questionable sampling techniques used to calculate CRD waste totals 2. Public waste collection information is typically the only records used to make CRD waste estimations while private waste collection records are ignored due to privacy issues 3. Unwillingness by the construction sector to accept that their industry has a waste problem because of weak waste collection procedures
2. Complex and Variable Waste Mixes • Different project types with different waste mixes	1. Residential versus commercial/industrial/institutional projects: residential waste is typically less in volume and comprised of wood, shingles, concrete, etc… while commercial/industrial/institutional project waste is greater in volume and generally the materials relied upon include steel, brick, concrete, etc… 2. Depending on the project construction versus renovation versus demolition will influence whether the waste generated is clean versus contaminated
• Regional differences	1. The type of materials used on a project depends on local resources, price of material, and availability. Consequently, the waste produced on a project site will be affected by these three factors

3. Reasons why Landfilling is Favored over other Management Options

- General

1. Often viewed by the construction industry as the fastest, cheapest, and easiest disposal method
2. False belief that tipping fees at recycling centers will be more expensive
3. Industry unwilling to adopt alternative waste practices because of a resistance to change current behaviors
4. Low cost of raw materials makes manufacturing new products cheaper than if these same products were made from recycled materials
5. Greater number of landfill facilities exist compared to recycling facilities
6. CRD waste that is recycled is usually considered low-grade quality and therefore not in high demand
7. CRD waste whether it is clean or contaminated can easily be landfilled. On the other hand, contaminated CRD waste that goes for recycling is more difficult to handle
8. Need only one waste container on-site to collect all CRD waste for landfilling
9. With landfilling, no extra time or waste containers are needed compared with alternative waste management options that require appropriate source separate of waste

- Ontario

1. Limited provincial regulations regarding the disposal of construction waste
2. Loopholes in the regulations that exist– only applies to projects that are over 2000 square meters in size and waste that is clean
3. Lack of enforcement by MOE for regulations that are in place and that deal with construction waste
4. Regulation avoidance to circumvent added disposal costs: transporting CRD waste to United States landfills since this option is cheaper than if the

material was recycled in the province

5. No incentive to encourage alternative management approaches

6. Limited resources, equipment, and funding dedicated towards finding more sustainable CRD waste management options

4. Project Related causes of Avoidable Waste Generation	1. Site activities - site preparation, excavation, foundation work, framing, metal work, wiring, plumbing, insulation, paint, drywall, paint, exterior finishing, and roofing 2. Poor site control by the general contractors because there are more important issues to deal with 3. Mismatch between standard size materials sold and the architectural design of the structure (bad planning and design) 4. Ordering errors whether buying too much of a product or purchasing the wrong material 5. Specification changes in which the crew is unaware of 6. Material damage during transportation due to the material not being securely attached to the truck and/or stacked wrong 7. Custom design resulting in excess material off-cuts in order to fit the unique design 8. Inappropriate storage of materials on-site – stored in heavy traffic flow areas or expose to weather elements which results in the material becoming damaged 9. Limited education given to construction industry regarding proper waste prevention and environmentally appropriate disposal techniques 10. Limited regulations and enforcement regarding the management of CRD waste

Chapter 5 Gypsum Wallboard Waste Management Issues

5.1 Gypsum Wallboard

5.1.1 Background on Gypsum

Gypsum is a naturally occurring mineral that is not only abundant in nature, but is also found on every continent of the world (McCamley, 2004; Sittinger and Sittinger, 2005). Pure gypsum is chemically known as calcium sulphate dihydrate and has a chemical formula of $CaSO_4 \cdot 2H_2O$ (Olsen, 2001; Panagapko, 2006). By weight, 79% is by calcium sulphate while the remaining 21% is water (Way Resources, no date). Typically, this fine grained mineral is white in colour, unless impurities exist which can alter its pigment to an assortment of colours including: brown, yellow, orange, and grey (Olsen, 2001; Panagapko, 2006; Sittinger and Sittinger, 2005). The mining of gypsum has occurred for thousands of years and will continue to occur due to the characteristic strength and manipulative abilities of this material (McCamley, 2004; Panagapko, 2006).

When gypsum minerals are processed, the crystals found in the sedimentary rock beds on the bottom of marine basins are taken and ground into fine minerals (Sittinger and Sittinger, 2005). Once the gypsum is converted into a powdery substance, these minerals are heated up between 280 to 320 degrees Celsius (^oC) in order to alter the chemical property of gypsum (Panagapko, 2006). When three-quarters of the water within calcium sulphate dihydrate has evaporated, gypsum is converted to hemihydrate gypsum ($CaSO_4 \cdot ½H_2O$) or stucco. With the addition of water this substance is transformed into a slurry paste that is extremely malleable. Once the paste hardens it becomes as hard as rock. The fact gypsum can easily be converted into any desired shape when wet and then turned into a solid rock when dried is a major reason why gypsum minerals are so heavily used today (Olsen, 2001; Panagapko, 2006; Sittinger and Sittinger, 2005). Gypsum composition will dictate whether it is classified as either calcined or uncalcined gypsum. Calcined gypsum involves crude gypsum losing three-quarters of its water composition through the use of heat. By converting gypsum into hemihydrates gypsum, it is used in the manufacture of wallboard and other plaster products. On the other hand, uncalcined gypsum is crude gypsum that has been ground into a powder form. This type of gypsum is used in the production of Portland cement and as agricultural fertilizers. In order to differentiate between these two outputs depends on whether crude gypsum is heated or unheated and what product this material will be made into (Founie, 2007). The 2006 average selling price in the United States for one ton of crude gypsum was $9.08; for one ton of calcined gypsum it was $17.63; and for one ton for uncalcined gypsum it was either $24.40 if used for agricultural purposes or $15.23 if employed in the production of Portland cement (Founie, 2007).

Over the years, great steps have been developed to lessen the adverse environmental impacts associated with mining gypsum. One of the greatest improvements has been an overall decrease in the amount natural gypsum mined. This reduction is due to an increase in production of synthetic gypsum (Panagapko, 2006). It was discovered that gypsum minerals can be created artificially through the collection of by-products from flue gas scrubbers in coal-fired power plants. With environmental regulations continually getting tougher with respect to the amount and type of emissions released from coal-fired generation, technology is now able to capture some of these harmful emissions (Nature's Way Resources, no date; Panagapko, 2006). The by-products from these emissions are materials with the chemical composition needed to produce synthetic gypsum or flue gas desulphurization gypsum (Panagapko, 2006).

5.1.2 Gypsum Mineral Uses

It has been calculated that 91% of calcined gypsum is used in the manufacture of wallboard sheets. Of this amount 48% is used in the production of standard 1/2 -inch (in.) drywall sheets, 30% is used in the construction of type X wallboard (extremely fire retardant), while the remaining 13% is employed in the assembly of wallboard sheets that range in thickness from 1/4 to 1 in. but excludes 1/2-in. (Founie, 2007). Other types of plaster production (art and dental) and specialized wallboard comprise the remaining 9% of calcined gypsum (Panagapko, 2006). As noted above, uncalcined gypsum is used in the production of Portland cement and as an agricultural fertilizer (Founie, 2007). Consequently, 65% of uncalcined gypsum is consumed in Portland cement to slow down its hardening time while the remaining 35% is used for agricultural purposes. In the latter case, the benefits include the following: neutralizes acidic soil, improves soil permeability, increases soil nutrients, softens and improves soil structure, leaches sodium salts of the soil, and decreases water runoff and soil erosion (Founie, 2007; Nature's Way Resources, no date; Panagapko, 2006). The overall consumption of natural and synthetic gypsum in North America is split into three categories: wallboard manufacturing (75%), cement production (10% -15%) and agricultural and industrial processes (10%). It is clear that wallboard manufacturing plays a significant role in the total amount of gypsum minerals consumed (Panagapko, 2006).

5.2 Background on Gypsum Wallboard

Although gypsum minerals have been used for thousands of years, only recently was gypsum wallboard invented. Prior to drywall production, gypsum was used in the pyramids of Egypt as both an interior plaster as well as a wall mortar. It was heavily used by the Romans and Greeks for sculptures and as a casting material. It was also used in the 1800's by the Europeans as wall covers and by the North Americans as agricultural fertilizer (Gardner, 2005; Sittinger and Sittinger, 2005).

The invention of wallboard revolutionized how gypsum minerals would be used in the future. The first type of wallboard was manufactured from straw paper and tar, but it was unsafe due to high flammability. For the next eight years (1880-1888), several wallboard prototypes were created with varying degrees of success (Gardner, 2005). In 1888, Sackett decided to sandwich Plaster of Paris between several layers of felt paper. Although there were problems with this prototype including the eroding of the felt paper, it was a start in the right direction. Advances in the workability of plasters and better paper backing led to improvements in the design and usefulness of wallboard (Gardner, 2005; Sittinger and Sittinger, 2005). By 1894, Sackett refined his processes so much that he was able to obtain a patent for his invention. By 1901, Sackett started mass producing wallboard and was able to manufacture over 5 million square feet (ft^2) of this product annually (Gardner, 2005). USG Corporation purchased Sackett Plaster Board Corporation in 1909, based on his innovative technology (Gardner, 2005). Once the USG Corporation took control of Sackett's operation, plasterboard or wallboard as it is known today exploded onto the market. It gained acceptance over other wall materials, such as traditional wood or plaster walls during World

War I, because of its fire resistant properties and the ease associated with building temporary homes for military personnel (Gardner, 2005; Sittinger and Sittinger, 2005).

5.2.1 Creation of Gypsum Wallboard and its Benefits

Today wallboard is sold in a variety of sizes, thicknesses, and protective fire resistant coatings (Gardner, 2005). Some of the most common standards sizes of wallboard can be seen in table 5.1.

Table 5.1 Standard wallboard prosperities (Lafarge North America, 2007)

Length	8 ft.	8 to 12 ft.	8 to 16ft.
Width	4 ft.	4 ft.	4ft. 54 in.
Thickness	1/4 in. (6.4mm)	3/8 in. (9.5mm)	1/2 in. (12.7mm)
Weight	16 kg/sheet	18.9 kg/sheet	23.2kg/sheet

Since its initial creation in 1888, wallboard has become the most common wall structure used in North America. Some key factors making this material such a desirable building material are that it is lighter than traditional wall materials, manufactured inexpensively from an abundant resource, strong and durable, an extremely good insulator, moisture-resistant, and naturally fire-resistant (Binggeli. 2008; Sittinger and Sittinger, 2005).

Wallboard can be purchased at almost any building supply store and is sold in a number of different types and sizes depending on where it is installed and what features are desired (see table 5.2). Although wallboard is relatively inexpensive compared to other wall materials, there is still a broad range in prices. The more materials and/or chemicals added to a panel, the higher the cost. The wallboard types listed in table 5.2 are sold in a wide selection of panels having varying features and sizes (Binggeli, 2008; National Gypsum, 2008). For instance, some Type X wallboard is sold with a higher fire resistant rating while other Type X wallboard is sold with a lower insulation value. These differences lead to a spectrum of wallboard prices.

Table 5.2 list of the most common types of wallboard products sold (Binggeli, 2008; National Gypsum, 2008)

Wallboard Types	Unique Specifications of the Product	Common Areas of Uses
Moisture resistant wallboard (green board)	-Oil additives result in the paper face being water repellant -Moisture resistant core	-Areas where there is high moisture (washrooms and sinks) -Used as a backing for the laying of ceramic tiles
Foil-back gypsum wallboard	-Layer of aluminum foil is laminated to back -Is vapor retardant	-Exterior/interior wall and as ceiling tiles
Gypsum board plaster base (blue board)	-Absorptive paper face -It bonds easily to veneer plaster	- walls that are susceptible to water and mold
Fire resistant wallboard (Type X)	-Core of wallboard is treated with various glass fibers and chemicals that make it fire, mold, and moisture resistant	- Interior walls
High-impact gypsum wallboard (subset of Type X)	-Contains a Type X core -Fiberglass mesh is embedded into the core -Increases strength and durability to protect against penetration	-walls where surface durability, penetration, fire, mold, moisture, and mildew are a concern.
High-abuse gypsum wallboard (subset of Type X)	-Contains a Type X core -heavy mold/mildew resistant paper backing	-walls where mold/mildew are a concern
Prefinished gypsum wallboard	-Decorative finish (textile, vinyl, and/or printed-paper surface)	-Demountable partitions
Acoustically enhanced gypsum wallboard	-Layer of viscoelastic damping polymer	- areas where there is a high transmission of sound

In estimating the cost of a wallboard panel two factors need to be considered: what is the wallboard type and size and what is the condition of the housing market (House Flipping Helper, 2008). In early 2008, due to a slumping housing market a standard 4'x 8' x 1/2"wallboard panel could be purchased for as little as $5.95US while higher end panels cost as much as $18.95 US (Home Depot, 2008A; Lowe's, 2008A). Fasteners (drywall screws), joint tape, jointing compound, and corner bead (finishing strip used on the corners) are all additional materials needed to construct wallboard walls (Binggeli, 2008; Home Depot, 2008A; House Flipping Helper, 2008). These extra materials can range in price from $.25 to $.55 US per square foot with the average being $.40 US per square foot. Cost of labor is another expense associated with wallboard installation (House Flipping Helper, 2008).

Although homeowners can install wallboard themselves, the number of hours it takes and the added cost with purchasing the necessary equipment needed to hang the wallboard makes “do it yourself” installation impractical. With professional drywallers, the cost for installations is based on how much time it will take to hang and to finish the walls divided by the number of panels needed for the area (Keating, 2009). Installation can cost anywhere from $25.00US per sheet to as much as $60.00 US per sheet which equates to $.85 US to $1.15 US per square foot (House Flipping Helper, 2008). The cost breakdown with wallboard usage is: 1/3 is for materials, 1/3 is for hanging, and 1/3 is for finishing (Binggeli, 2008). The steps involved to hang drywall are simple and entail the following:

1. Determine the number of wallboard pieces needed
2. Cut the pieces to the appropriate sizes
3. Fasten the drywall pieces with either fasteners or nails to the wood or metal framing studs
4. Apply a coat of compound to the fasteners and joints that are showing
5. Wait at least twenty-four hours before sanding the compound down
6. Apply another coat of compound to the same areas where it was previously used
7. Once again wait at least twenty-four hours before sanding the area down
8. Apply one more layer of compound to the area where the joints and fasteners are
9. Paint or wallpaper the wall if desired (Binggeli, 2008, pg. 143)

Although wallboard is easy to install, it can be quite time consuming especially if you do it yourself. Hiring a professional has four major benefits: labor is saved; the project will be finished in a shorter period of time; less waste will be produced; and finally the contractor is responsible for storing the wallboard and dealing with the waste generated at the project site.

5.3 Background Information on Gypsum Wallboard Waste

Gypsum wallboard waste is one particular product identified in the construction industry as difficult to manage even though it shares many of the same characteristics as past problematic waste. The damaging environmental impacts connected with it and its high annual disposal rate are reasons why research needs to be devoted to this material (Cochran and Beck, 2003; Laquatra, no date; Marvin, 2000). Although opportunities exist to manage this product in a more environmentally conscious manner, various factors have discouraged this action (Laquatra, no date).

5.3.1 Creation of Wallboard Waste

Wallboard waste is typically generated from four different activities which include the construction of new buildings, the renovation of existing structures, the demolition of older buildings, and the actual manufacturing process of the wallboard itself. All of these factors play a role in the amount of discarded wallboard (McCamley, 2004; Recycling Council of Ontario, 2005). It has been calculated that 17% of the global wallboard market ends up as scrap drywall annually. A breakdown of this total illustrates that 3% to 5% of gypsum scrap comes from the manufacturing processes, 5% to 10% is created through off-cuts during the installation of drywall, and the remaining 1% to 2% is generated through renovation and demolition projects. If a greater percentage of this wallboard waste was recycled rather than landfilled or stockpiled, it could lead to the remanufacturing of wallboard at levels equivalent to 2.5 to 4.5 Mt. In terms of the overall percentage of wallboard waste generated at projects sites, it ranks only behind wood and concrete in waste mass (McCamley, 2004). It should be noted that at new project sites, wallboard waste on average comprises 27% of the overall waste produced while at demolition projects it makes up 21% of the waste. The substantial amount of wallboard waste generated at these sites makes this particular waste a source of concern (Recycling Council of Ontario, 2005). Participation in reuse and donation programs for uncontaminated wallboard waste has been one step this industry has taken to reduce its wallboard waste (Marvin, 2000). Unfortunately, still a large volume continues to be produced and is still being discarded in landfills (Saotome, 2007).

5.4 Environmental Impacts of Wallboard through its Lifecycle

A number of adverse environmental impacts are associated with the production and disposal of wallboard waste. Mineral extraction, transportation and energy cost, along with landfilling, are all factors highlighted in the literature. With each of these actions, numerous negative impacts arise that each contributes unfavorably to the overall health of the environment (McCamley, 2004).

5.4.1 Mineral Extraction

Most North American mines are well designed and well-regulated to minimize as many environmental impacts as possible. Mining, however, is still considered one of the most destructive actions to impact the earth (Milani, 2005). Although steps have been taken to reduce these impacts, numerous environmental implications still arise. Because literature pertaining to gypsum mining and its harmful impacts is limited, the following sections are only a general discussion about commonly cited environmental problems connected with mineral extraction.

The first problem associated with mining, whether the pit is opened or closed, is alterations to the natural habit. Problems associated with mineral extraction include: 1) the creation of roadway systems to transport minerals to and from the mine; 2) tree and shrub removal in order to construct the roads and mines; 3) excavation of land; 4) alteration of waterway systems through the discharge of waste water; and 5) the dumping of rocks, tailing and slag (Cottard, 2001; Union of International Associations, 2003). With habitat modification, biodiversity loss occurs as does the extinction of plants and animals, the resettlement of animals to less suitable habitats, and changes to the aquatic and terrestrial ecosystems (Ecosystem Restoration, 2004). A second concern is the problem of acid mine drainage. This occurs when soil, rock, waste rock, and tailing are exposed to air and water. The fact that these materials typically contain sulphide minerals, such as pyrite, results in oxidation and the release of large amounts of iron and sulphate into surface and groundwater.

Acid generation creates adverse impacts on the aquatic environment by causing fish and plant death (Cottard, 2001; Ecosystem Restoration, 2004). The third issue involves soil disturbance. Altering soil characteristics can lead to erosion and sedimentation problems, which negatively affect soil organisms, reduce vegetation cover due to high angle slopes, and create a loss of soil nutrients (Ecosystem Restoration, 2004). Pollution in the form of air, land, water, and noise poses the fourth environmental problem. Some commonly cited air emissions are carbon oxides (COx), sulphur oxides (SOx), nitrogen oxides (NOx), methane, and different types of radioactive and toxic dusts (Cottard, 2001). In regards to land and water contamination, many of the same pollutants affect both areas. Most of these toxins are released during the processing stage and include oil, petroleum products, solvents, and acids (Ecosystem Restoration, 2004). Finally, there is noise pollution. It occurs at various stages of the mining process from the initial blasting of the mine to the movement of trucks/trains to and from the site (Cottard, 2001; Union of International Associations, 2003). The list of environmental impacts associated with mining is extensive. It is essential that every attempt be made to reduce mineral extraction to lessen these adverse impacts.

5.4.2 Transportation and Manufacturing Costs

When gypsum minerals are extracted, they are transported via ship, rail, or truck for further processing. The amount of energy consumed to move these materials from one place to another and then to process these minerals into usable products represent additional factors that contribute negatively to the overall health of the environment. Because most mines are located in isolated areas, products created from these minerals have to travel to urban centers. Resulting fuel combustion (gas, diesel, and/or oil) in transportation vehicles releases enormous amounts of greenhouse gases. Further emissions are also discharged when various machines are used to manufacture the wallboard (New West Gypsum, 2003). Information that specifically deals with the environmental impacts associated with gypsum mineral transportation and product development is limited. Research conducted on wallboard energy consumption has revealed that mineral extraction of gypsum is not as energy intensive as compared to its transportation for processing. It has been calculated that 85% of the total amount of energy consumed for a sheet of wallboard is during the transportation stage. In

Ontario, gypsum minerals on average have to be transported a distance of 230 kilometers (km) (one-way) for processing as compared to 30 km if wallboard waste is taken to a place where it can be either reused or recycled. Each tonne of wallboard recycled results in 800 mega joules (Mj) of energy saved from transportation (Recycling Council of Ontario, 2005).

Although a number of different shipping options exist the most common vehicle used to move gypsum wallboard, are transport trucks. These trucks are typically employed when wallboard is moved from the manufacturing warehouse to stores, from stores to project sites, and from project sites to disposal facilities (Recycling Council of Ontario, 2005). Because trucks play a key role in the transportation of wallboard, it is important to know the operating cost to run this type of vehicle since it will influence the purchasing price of wallboard. When calculating their costs a number of variables must be considered, and include: fuel cost, size and type of truck (5 axle versus 6 axle, flatdeck versus semi trailer), driver's wage, hauling weight, licensing, insurance, truck maintenance, permits, and taxes (Transport Canada, 2000; Transport Canada, 2005). To determine the average cost to run a truck a local transporting company was contacted. The company estimated that the average cost to run a truck as of March 2009 is $1.04CAD per mile (Transport Company, 2009). It should be noted that similar cost per mile can be expected with other materials transported by truck.

5.4.3 Landfilling Wallboard

It is estimated that 64% of all wallboard waste produced comes from new construction projects (Binggeli, 2008; Saotome, 2007). The low level of contamination associated with new construction over renovation and demolition projects should help to divert this waste away from landfills. In most parts of Canada, this is not the case and landfilling is still the preferred disposal choice (Saotome, 2007). When wallboard is landfilled, a number of adverse environmental impacts result. First, when wallboard is landfilled it consumes a tremendous amount of valuable landfill space because of how bulky this material is. It has been estimated that 1% of all landfill space in North America is occupied by drywall waste (McCamley, 2004). Second, this waste produces substantial amounts of a noxious gas known as hydrogen sulphide under anaerobic conditions. In large quantities, this gas can have serious impacts on human health. Levels higher than 1,000 parts per million (ppm) can result in human death (Binggeli, 2008; Marvin, 2000; McCamley, 2004; Musick, 1992; Saotome, 2007). A third environmental problem is the leaching of metallic sulphide into groundwater when this material is disposed in unlined landfills. When the water is contaminated with this leachate, fish die due to the toxic nature of the water (Anonymous, 2003; Marvin, 2000; McCamley, 2004; Musick, 1992; Saotome, 2007). Although other adverse impacts exist with landfilling drywall, the three previously noted problems tend to pose the worst environmental outcomes. It is vital that change occurs within this industry in the area of waste disposal practices.

5.5 Product System Vulnerability to Failure

Product vulnerability is an important issue that needs to be discussed when looking at the lifespan of wallboard. To understand whether any vulnerability exists with a product, knowledge about how the entire system operates is important. Identifying potential stresses within the system is critical in helping it avoid breakdown. A clear understanding of all the interactions that can transpire and of all the actors involved in the system's operations is important in making predictions on how well or not so well the system is able to handle new changes (Gibson et al, 2005). In the gypsum wallboard system, there are a number of vulnerable areas that could influence its behavior. Because no literature exists that can pinpoint potential areas where system failures could happen, educated guesses based on all the information learned about gypsum wallboard were made. Areas where problems could arise include mining problems, resource availability, transportation issues, manufacturing troubles, equipment/machinery failures and human error. Although these areas were identified as potential target zones for system failure, the probability of it occurring is low. It is low because gypsum wallboard is a well-established system, in which few problems have arisen over the years. The comprehensive knowledge about how this system operates helps to identify potential impacts that could arise if changes were to be made to the system.

5.6 Wallboard Waste Management Options

Many of the solutions discussed in *Waste Management Options for CRD Waste* section can also be applied to the gypsum wallboard waste situation. Better project design, the implementation of waste minimization techniques, and seeing whether alternative wall systems are a viable option, are all choices that could help reduce overall disposal levels of wallboard waste.

5.6.1 Waste Minimization: Reduce, Reuse, and Recycle

Source reduction of drywall should be a waste management option considered. Designing projects with dimensions that can accommodate available gypsum wallboard lengths and paying particular attention to product ordering are two key factors that could decrease the amount of wallboard material that is left over (Johnston and Mincks, 1992; Recycling Council of Ontario, 2005). However, reusing wallboard depends on the condition of the wallboard waste. In cases where the wallboard is used (painted, taped, and nailed), reuse is not a viable option. In instances where drywall waste is comprised of off-cuts from new wallboard, reuse is an acceptable waste management alternative as long as the off-cuts are large enough. When discarded sheets are half size or larger, they should be reused or donated to nonprofit organizations (Marvin, 2000; Recycling Council of Ontario, 2005).

Although all sizes of drywall off-cuts should be reused, this is not the case. Drywallers are hesitant to reuse off-cuts due to the added time needed to construct a wall. Because drywallers are paid based on the number of square feet they install, the use of wallboard off-cut is not an option due to extra time needed to tape and nail several small pieces together (Johnston and Mincks, 1992; Recycling Council of Ontario, 2005). The same can be said when this material is donated. Donation services are only willing to accept drywall pieces that are half-size or larger. Any pieces smaller are either brought to recycling facilities or landfilled (Marvin, 2000). If these waste reduction and reuse actions were fully adopted by the construction industry, it is estimated that a 50% decrease in wallboard waste generation totals would be experienced. If these waste solutions are ever going to be fully accepted by this industry, economic incentives, educational training and stricter waste management regulations are necessary (Johnston and Mincks, 1992).

Drywall that remains after these waste minimization techniques have been employed should go for recycling. In cases where wallboard waste is recycled, a number of factors must be considered as each will play a role in what this waste material can be reprocessed into. Wallboard waste has tended not to be recycled due to the false belief that the product's high moisture content and the industry's inability to completely remove all the paper backing prevent recycling. Over the years, technological advancements have been developed to deal with these two problems. Although the technology exists, few recycling facilities in North America possess these machines (Musick, 1992). For instance, in Southern Ontario, although wallboard waste can be recycled at three different facilities (New West Gypsum (NWG), Sittler Environment Incorporated, and Try Recycling), only one facility, NWG, has this state of the art machinery. This sets NWG apart from the other recycling facilities in terms of the type of wallboard waste it can recycle and the end product produced. Although all three facilities can handle clean and almost any type of contaminated wallboard excluding dirt covered and asbestos filled, NWG can also recycle wallboard sheets that have yet to make it to the drying phase of manufacturing. In terms of the end products, NWG is able to recycle wallboard sheets into a coarse white powder that is brought to a nearby gypsum wallboard manufacturing plant, Certainteed, for inclusion in the manufacture of new wallboard. On the other hand, at the other two facilities, small gypsum chips are the end product produced. These chips are sold as soil fertilizer and as an ingredient in compost (see Appendix G). This difference in recycling technology and techniques is why NWG is recognized as a wallboard recycler in Southern Ontario while the other two companies are not (Johnston and Mincks, 1992; Marvin, 2000; Musick, 1992; Recycling Council of Ontario, 2005). Other uses for recycled gypsum include:

> ceiling tiles, Plaster of Paris, stucco additive, cement, filler and pigment uses, glassmaking, chemicals, kitty litter, animal bedding, dietary supplement in foods for nutrition, water treatment, flea powder, manure treatment, grease absorption, athletic field marker… mushroom growing, forestry and mine reclamation, nurseries, residential lawns, golf courses, composting, and manure management (Nature's Way Resources, no date, pgs. 4-5).

How and what types of wallboard can be recycled is influenced by location of the nearest wallboard recycling facility. In instances where wallboard is contaminated, options are somewhat more limited. In situations where the wallboard waste is clean, it can be placed into wood chippers and be ground down into fine chips. This waste material can then be used as an agricultural fertilizer or be brought to facilities where it is then converted into one of the products listed above. CRD recycling facilities, which accept wallboard waste, but do not have the wallboard recycling technology available, will process the waste in similar manner to chipping it up in a chipping machine (Block, 2000). Once all of these actions have been taken any wallboard that remains has a few options for final disposal.

5.6.2 Final Disposal Options

Discussions regarding waste disposal practices have usually revolved around recycling because oftentimes this option is perceived as being the best solution (Peng et al, 1997). However, recycling is not the only option available. Landfilling, incineration and ocean dumping are additional choices that exist (Carr and Munn, 2001; Johnston and Mincks, 1992; Laquatra, no date). Because landfilling was previously discussed in great depth under section 5.4 *Environmental Impacts of Wallboard through its Lifecycle* this particular waste option will be ignored in this discussion. Like landfilling, drawbacks have also been identified with both incineration and ocean dumping. In the case of incineration, the release of sulphur dioxide gas has been a problem commonly cited. When wallboard is heated, the sulphate found in this material is converted into sulphur dioxide gas (Laquatra, no date; Marvin, 2000). The problem with this gas, other than polluting the air is that it, “reduces the alkaline scrubbers ability to remove other acidic gases” (Marvin, 2000, pg. 3). Ocean dumping, whether the wallboard waste is contaminated or clean will have little influence on the aquatic environment. A study conducted by the Canadian government found that uncontaminated wallboard waste has minimal impact on the environment because many of the minerals that comprise wallboard occur naturally in the oceanic environment (Burger, 1993; Laquatra, no date). The idea of unloading large quantities of wallboard waste into the ocean has not been well received by the public. Consequently, this option has been abandoned (Laquatra, no date). The dismissal of these two disposal options combined with the adverse impacts connected with landfilling, only leaves recycling as a viable option. Although problems exist with this choice, the ability to reprocess the material so it can be used in new products is often viewed by the public as being the best solution available today (Peng et al, 1997). Understanding all of the available disposal options and identifying which of these options are feasible for the management of wallboard waste in Southern Ontario, will hopefully lead to the adoption of successful and sustainable wallboard waste management practices.

5.7 Alternative Wall Systems

As previously stated, the construction industry tends to favour gypsum wallboard over alternative wall systems because of its price and the ease associated with installing it. However, the amount of waste generated at project sites and the adverse environmental impacts connected with wallboard use is why alternative wall materials need to be examined (Public Works and Government Services Canada, 2000; Sittinger and Sittinger, 2005). Composite panels, cement board, and plaster on metal lath are all alternative wall options that exist, but that are rarely used. In the case of composite paneling, there are nine different paneling options, but generally 90% to 95% of the board is made from recycled wood products. Because this product is primarily comprised of wood, one would think it would be easy to recycle. The plaster on metal lath wall option has many of the problems identified with gypsum wallboard. Although this wall material is considered different from gypsum wallboard, the plaster used in the construction of the walls is made from gypsum minerals. Consequently, many of the same damaging affect associated with gypsum wallboard also apply with this wall option as well (Public Works and Government Services Canada, 2000). For a more detailed discussion regarding the different wall material options available see Chapter 6, entitled Identification of Alternative Wall Materials.

5.8 Wallboard Waste Situation in Southern Ontario

In Southern Ontario, the most favored disposal choice for new and used wallboard waste is to landfill it. This option is preferred based on the ease associated with discarding all CRD waste in one central location (Cosper et al, 1993; Poon et al, 2001). The fact that the construction industry is only concerned with maximizing financial returns and minimizing time constraints for its implementation, is why landfilling remains the favored disposal option (Recycling Council of Ontario, 2005). If wallboard was recycled by the construction industry, it would require some source separation of the waste either on or off-site. By separating the waste into appropriate streams, slightly higher disposal costs would be incurred on the project (Cosper et al, 1993; Poon et al, 2001). However, other measures such as proper ordering and on-site planning, better material selection, use of standard size materials and donation of usable products before the waste was transported to the recycling facility would reduce the overall amount of waste being discarded (Cosper et al, 1993; Leverenz, 2002; Public Works and Government Services Canada, 2000; Recycling Council of Ontario, 2005). These source reduction actions would in turn lower the overall disposal costs since less wallboard waste would be recycled; however, the construction industry presently does not see it in this light. For a more detailed discussion on how wallboard waste is managed in Southern Ontario, see Chapter 7.

5.8.1 Obstacles Preventing Recycling of Wallboard in Ontario

Although some reuse and donations programs exist, the amount of wallboard going to these alternative options was minimal (Recycling Council of Ontario, 2005). Even though gypsum wallboard is considered to be a highly recyclable product, this disposal option is not employed in most of Ontario for a variety of reasons (Laquatra, no date). The main factors that currently prevent it from being recycled in most parts of Ontario or Canada include 1) limited free space to place added recycling bins; 2) added cost (minimal) to separate scrap gypsum from the rest of the regular waste stream; 3) additional transportation costs to bring the waste to either NWG or other CRD recycling facilities; 4) lack of education by crew members to collect drywall off-cuts; 5) convince of having a one bin where all waste can go; 6) abundance of gypsum minerals and the low cost to manufacture it into wallboard; 7) low embodied energy makes recycling economically unfeasible; and 8) finally the difficultly to change established practices and attitudes (Laquatra, no date; Recycling Council of Ontario, 2005; Saotome, 2007). These factors have contributed significantly to the minimal action taken to eliminate wallboard waste from Ontario landfills.

Regulations represent yet another factor that influences the current disposal situation. The current regulations are viewed by the construction industry and the public alike as being extremely weak due to a lack of governmental enforcement (Recycling Council of Ontario, 2005; RIS International Ltd., 2005; Saotome, 2007). It should be noted that the same regulations and problems discussed in section 4.5 entitled *Ontario Regulation Pertaining to CRD waste*, also apply to the gypsum wallboard waste situation. These factors have made the option of recycling all that much more undesirable for the construction industry (Marvin, 2000).

5.8.2 Action Taken in Vancouver to Make Wallboard Recycling a Viable Option

In areas where recycling wallboard waste has become a reality, significant planning and gradual steps were taken to make this disposal option work. The Greater Vancouver Region of British Colombia is one jurisdiction that has taken the progressive steps needed to get wallboard waste recycled. This city decided to ban all wallboard waste from entering municipal landfills (McCamley, 2004; Musick, 1992; Saotome, 2007). In a study conducted by McCamley (2004), his research was able to identify the factors that made wallboard recycling a success. These actions included: a ban that no longer allowed the disposal of wallboard waste in municipal landfills in Vancouver, a reduction in recycling tipping fees so recycling price was just as competitive as the landfilling tipping price, a steady supply of wallboard waste being brought to the recycling facility daily, and a new set of regulations that were introduced and that were strictly enforced (McCamley, 2004).

In the case of Vancouver, recycling wallboard waste was very successful. In examining the current situation in Ontario, there are factors that have and will continue to hinder the recycling of wallboard waste. First, is the false belief that NWG is the only wallboard recycling facility in Ontario, which is not the case. A further factor inhibiting this process is the lack of regulations concerning this waste. Furthermore, there are no disincentives for landfilling wallboard waste (Recycling Council of Ontario, 2005; Saotome, 2007). If recycling wallboard waste is ever going to be a reality in Ontario, this province needs to change its current practices.

5.9 Summary

The composition of gypsum wallboard makes this product a unique building material because of a number of factors, which include fire and moisture resistance, light weight, strength, durability, low purchasing cost, and ease of installation. Although wallboard is the most favored wall system used, the waste connected with its manufacturing, installation, and demolition makes this material challenging to manage. Because wallboard can be made from naturally occurring as well as synthetically made gypsum minerals, there is an abundant supply of this material. With such large quantities of gypsum, the cost to manufacture wallboard is relatively low. Cheap production costs limit the attention that is directed towards waste reduction techniques or its proper management. Since gypsum wallboard has such a low embodied energy cost, recycling is not widely accepted by the construction industry because of the added costs typically associated with this disposal method. Consequently, landfilling wallboard is the most accepted waste management option as it is not only the easiest, but also the cheapest.

The literature has highlighted the wide range of alternative management options that exist to deal with wallboard waste. These management options include material changes (composite paneling, cement board, plaster on metal lath) and changes in practices (use of standard size material; product deconstruction; better material selection, planning, site control, transportation practices, and on-site material storage; up-to-date inventory list; accurate ordering; correct design; source separation; enforcement of contractual clauses; increase landfill tipping fees; product redesign; educational programs; and just-in-time delivery). Due to a lack of encouragement and acceptance by both the construction industry and government alike, minimal action is being taken to improve the management of this situation. A summary of current challenges facing the management of wallboard waste can be seen in table 5.3.

Table 5.3 Summary of key issues influencing wallboard waste management (Cottard, 2001; Johnston and Mincks, 1992; Laquatra, no date; Marvin, 2000; McCamley, 2004; Recycling Council of Ontario, 2005; Saotome, 2007; Union of International Associations, 2003).

Challenges of gypsum wallboard management	Impacts from these challenges
1. Adverse Impacts Connected with Gypsum Wallboard Production • Mineral Extraction	1. Natural habitat alterations: • Creation of roadway systems to transport the minerals from the mine to the manufacturing plant • Elimination of trees and shrubs in order to create the roadway systems as well as the mine itself • Excavation of land to determine where the mine should be constructed • Alteration to the waterway system through the discharge of wastewater from the mining process • Biodiversity loss due to manmade changes that result from mine creation • Resettlement of plants and animals to less suitable habitats • Variation to terrestrial and aquatic ecosystems because of the infiltration of humans and machinery within the area 2. Acid mine drainage: • Release of large amounts of iron and sulphate into surface and groundwater

3. Soil distribution:

    - Leads to erosion and sedimentation problems which negatively affects soil organisms
    - Reduce vegetation cover due to high angle slopes created by the mine and roadway systems
    - Loss of soil nutrients because of soil compaction that resulted from the creation of the roads

4. Pollution:

    - Emissions released into the air include carbon oxides, sulphur oxides, nitrogen oxides, methane, and different radioactive toxins and dust
    - Contaminates that infiltrate the land include oil, petroleum, solvents, and acids
    - Pollutants that enter the water include oil, petroleum, solvents, and acids
    - Noise pollution includes the blasting of the mine and the movement of trucks and trains to and from the mine

- Transportation Costs

1. Movement of minerals via ship, rail, and/or truck from the mine to the manufacturing plant, from the manufacturing plant to the store, and

	from the store to the job site
	2. Consumption of natural resource to power the transport vehicles used to move the minerals – gas, diesel, and oil
	3. Release of numerous greenhouse gases during mineral transportation (on average gypsum minerals travel 230 km (one-way) for processing)
• Manufacturing Costs	1. Consumption of natural resource to power the machines used to process the minerals – gas, diesel, oil, and electricity
2. Wallboard Waste Conditions	
• Clean	1. Wallboard waste that is clean usually comes from construction and renovation projects as well as wallboard manufacturing plants
• Contaminated	2. Wallboard waste that is contaminated comes from either renovation or demolition projects
3. Reasons why Landfilling is Favored over other Management Options	
a. General	1. Often viewed by the construction industry as the fastest, cheapest, and easiest disposal option
	2. False belief that tipping fees at recycling centers will be more expensive
	3. Industry unwilling to adopt alternative waste practices because of a resistance to change current behaviors
	4. Economically unfeasible to recycle even though it is highly recyclable

because of its low embodied energy

5. Abundance of gypsum minerals and the low cost to produce wallboard makes the manufacturing of it cheaper than if it was made from recycled wallboard
6. Greater number of landfill facilities results in smaller transportation costs since the waste does not have to travel as far for disposal compared to if it were brought to a recycling facility
7. No matter what condition the wallboard is in, it can be landfilled. On the other hand, contaminated wallboard that goes for recycling is harder to deal with
8. Lack of space on project resulted in no added waste bins on site that are designated for one specific type of waste
9. Added costs to source separate wallboard waste from other CRD waste (minimal)
10. Lack of education by crew members to collect and reuse drywall off-cuts

b. Ontario

1. Limited provincial regulations regarding the disposal of wallboard waste
2. Loopholes in the regulations that do exist – only applies to projects that are over a certain size and waste that is clean
3. Lack of enforcement for regulations that are in place
4. Regulation avoidance to circumvent added disposal costs: transporting wallboard waste to United States

	landfills since this option is cheaper than if the material was recycled in the province 5. Construction industry is not on the same page when it comes to wallboard management 6. No incentives to encourage alternative management approaches 7. Limited resources, equipment, and funding dedicated towards finding more sustainable wallboard management options 8. Only one recycling facility in Ontario that specifically specialized in wallboard recycling
4. Adverse Impacts Associated with Landfilling Wallboard	1. Consumes tremendous amounts of valuable land each year 2. Releases large quantities of hydrogen sulphide gas in anaerobic conditions 3. Leaches metallic sulphide into groundwater especially when wallboard is discarded in unlined landfills
5. Project Related causes of Avoidable Waste Generation	1. Equipment failure during manufacturing stage 2. Poor site control by the general contractor because there are more important issues to deal with 3. Mismatch between standard size materials sold and the architectural design of the structure (bad planning and design) 4. Ordering errors whether buying too much wallboard or purchasing the

wrong size or type of wallboard

5. Specification changes in which the crew is unaware of
6. Material damage during transportation due to the material not being securely attached to the truck and/or stacked wrong
7. Custom design resulting in excess material off-cuts in order to fit the unique design
8. Inappropriate storage of materials on-site – stored in heavy traffic flow areas or expose to weather elements which results in the material becoming damaged
9. Limited education given to construction industry regarding proper waste prevention and environmentally appropriate disposal techniques
10. Limited regulations and enforcement regarding the management of wallboard waste

Chapter 6 Assessment of Alternative Wall Materials

6.1 Material Change

The focus of this chapter is to examine alternative wall materials that could realistically replace gypsum wallboard in the future. This chapter centers on the principle of refuse/replace under the waste management hierarchy. The philosophy is by refusing to use wallboard and instead substitute it with other less problematic wall materials, it will eliminate wallboard waste generation totals because these panels would no longer be used. In assessing the different wall options, the factors examined were: environmental impacts of the product, financial cost, installation ease, maintenance level, product durability, aesthetic quality, panel rating, and product recyclability. Although numerous alternative wall materials exist (brick, concrete, and plaster), these products are not commonly used by the industry due to higher cost and installation difficulty. Because of these drawbacks, the alternative wall materials considered for this research were all products with which the construction industry has some familiarity with using. The wall materials that were examined were composite panels, cement board, and plywood. Preliminary examination of each recommended product was done to determine its feasibility for future implementation. It was determined that composite panels were the only realistic wall material option. The rest of this chapter discusses the benefits and limitations with using composite panels as an interior wall material. A short discussion about why cement board and plywood are not ideal wall materials is also included at the end of this chapter.

A lifecycle approach was attempted to identify the adverse impacts connected with composite panels. A detailed review of the literature indicated that there was a lack of research and resources dedicated towards information regarding product lifecycle (Rivela et al, 2007). In many cases the only information found came from the manufacturer's websites. Consequently, when it came to discussing the potential environmental impacts that arise with composite panels, many generalizations needed to be made. Because company websites and books were key data sources used to obtain information about this product, the lifecycle approach employed was weak. It is clear from the literature that further research needs to be devoted to the lifecycle of composite panels. Because no one has dedicated the time or energy to this area of research, a rough lifecycle approach was applied.

6.1.1 Wood Composite Panels

Engineered wood is also known as wood composite panel and composition board. This type of paneling system is primarily made from wood, a renewable resource. In manufacturing composite panels a wide variety of wood materials are used and include wood strands, fibers, particles, and veneers. Wood that can be used in the construction of these panels includes: hardwoods and softwoods, sawmill scraps, and wood waste. The loose wood scraps are bound together with adhesive glue to form a strong durable panel (Binggeli, 2008). Within the composition board there are a number of different sub-products such as plywood, flakeboard, oriented strand board (OSB), waferboard, particleboard, fiberboard, hardboard, medium-density fiberboard (MDF), and veneer sheets (see figure 6.1) (Binggeli, 2008). Although these nine products are all considered a type of composite board, how they are made, where and what they are used for, and how much they cost, differ substantially from one another (Binggeli, 2008; McKeever, 1997).

The reason why composite board was selected over solid wood products is the number of the environmental impacts associated with it. With solid wood panels, tree age and tree species are two important factors that play a role in deciding whether a particular tree is suitable for solid wood paneling production. However, with composite paneling, tree age and tree species have no impact on panel production. As a result, composite panels safeguard against deforestation of old-growth forests since recycled and recovered wood waste are the main materials used (APA, 2005B). In addition this type of paneling is less vulnerable to shrinking and swelling, less labor intensive to install, and finally more resource efficient to construct (Binggeli, 2008; McKeever, 1997). Although nine types of composite panels exist, MDF, OSB, and particleboard were the only panels examined. These three composite panels were selected because they were similar to wallboard in terms of function, cost, and installation requirements. In addition, discussion with local hardware employees indicated that these three composite products represented the best wallboard replacement options. Furthermore, in *Materials for Interior Environment*, Corky Binggeli (2008) a professor who teaches interior design at Boston Architectural College, also suggested these products as being suitable substitutes for gypsum wallboard. Finally, these types of panels have occasionally been used in the construction of interior walls. In 1999, at 20th Century Fox, MDF was used in the renovation of their post-production building. At the conclusion of the project, MDF was found to be an excellent interior wall material. Builders and employees alike favored it because it was not only more durable than traditional wallboard, but also more aesthetically pleasing to the eye (CPA, no date). The figure below is an illustration of the different types of composite panels available. The following section is a discussion of the processes involved in the manufacturing of MDF, OSB, and particleboard.

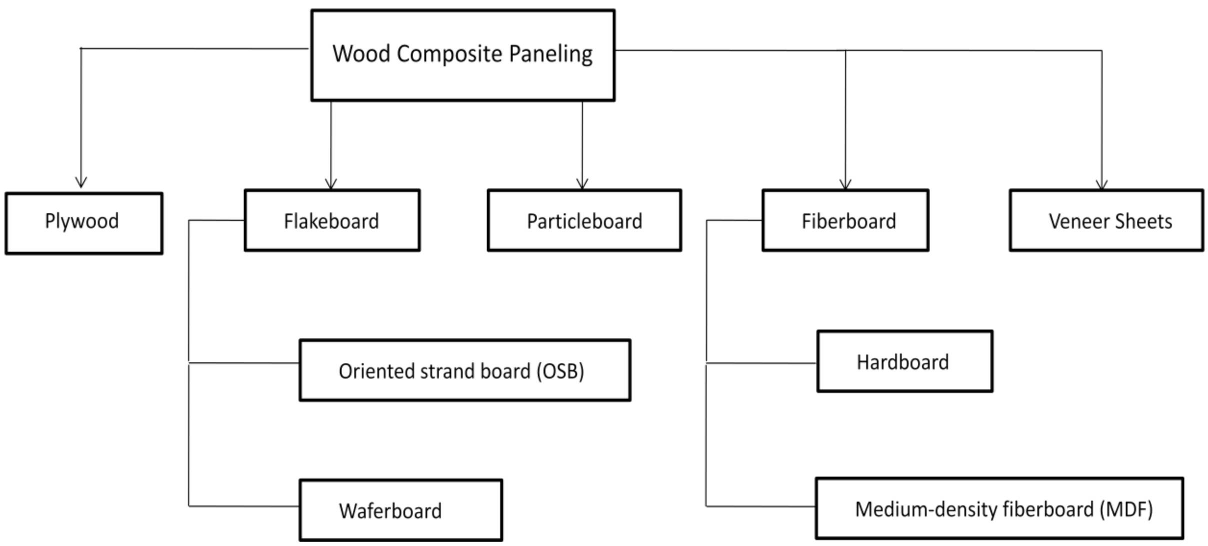

Figure 6.1 Breakdown of the various types of composite panels available (Binggeli, 2008; Rivela et al, 2007)

6.1.1.1 <u>Medium Density Fiberboard</u>

The main material used to construct MDF panels is wood. The wood that enters MDF manufacturing facilities is a combination of both wood chips and tree logs (Binggeli, 2008). Because MDF is made from wood chips, in instances where entire logs are brought to the facility, they are broken down into manageable sized chips. Debarking machines as well as cutters, chippers, and grinding machines are all used to transform the logs into small wood chips (US EPA, 2002C). The wood chips themselves come from a variety of different wood based businesses such as sawmill and plywood plants, furniture manufacturers, satellite chip mills, as well as whole tree chipping operations (Rivela et al, 2007; US EPA, 2002C). These chips are transported either by trucks or rail to the manufacturing facility for processing. Once on-site, all wood chips are washed thoroughly to remove any excess dirt or debris that may have accumulated on them (US EPA, 2002C). Both steam-pressurized digesters and pressurized refiner chambers are utilized to alter the physical properties of wood. The conversion of these hard chips into soft pliable chips allows the chips to be pulped for their wood fibers. Once the wood is in fiber form, it goes through a number of different drying and blending machines (Rivela et al, 2007; Tetlow, 2005; US EPA, 2002C). During the drying phase, rotary predryers, single-stage and multi-stage tube dryers are all used to remove as much moisture from the wood fibers as possible. Once the fibers are dried, they are moved to the blending stage. Resins such as urea-formaldehyde, phenol- formaldehyde, melamine-formaldehyde, and isocyanates, in addition to wax and other additives, are infused into the fibers (US EPA 2002C). Although there are two different ways these resins can be injected, the blowline technique is by far the most favored approach used. With this approach resins, wax, and other additives are combined with the fibers to create mats (Rivela et al, 2007; US EPA, 2002C). These mats are loaded in hot presses where heat and pressure are used to activate the resins. Once the resins have been stimulated, they bond with the fibers and create a solid panel (Binggeli, 2008; Rivela et al, 2007; US EPA, 2002C). The end product consists of a solid board that is not only moisture tolerant, but also has great sound insulation and damping properties (Binggeli, 2008).

6.1.1.2 Oriented Strand Board

OSD as well as waferboard are subcategories within flakeboard (Baker, 2002; Binggeli, 2008; US EPA, 2002A). Although flakeboard has been around since the early 1950s, OSB is a relatively new type of composite paneling that was only invented two and half decades ago (US EPA, 2002A). Because of its superior flexibility in comparison to waferboard, OSB has exploded onto the market and has become the most favored flakeboard available today (Binggeli, 2008). Construction of OSB begins with whole logs being brought to the manufacturing facility for debarking. Hardwoods (aspens) and softwoods (various pines, firs, and spruces species) are used in the construction of these panels (Binggeli, 2008;

US EPA, 2002A). Once the logs are debarked, they are cut into 2.5 meter (m) (8 feet (ft)) pieces, known as bolts. The bolts are then transported to a waferizer machine where the logs are sliced into wafers that are 3.8 centimeters (cm) (1.5 inch (in.)) wide by 7.6 to 15 (3 to 6 in.) cm long by .07 cm (.028 in.) thick (US EPA, 2002A). Rotary and conveyor dryers that range in temperature from 540^{o}Celcius (^{o}C) to 870^{o}C and 160^{o}C, respectively, are then used not only to dry the wafer pieces, but also to reduce the moisture content within them. All wafers are then screened to ensure the wafer panels are an appropriate size and that no impurities exist. The screen wafers are then moved to storage where they remain until they are needed. When the wafer pieces are taken out of storage, they are moved to the blender where various kinds of resins such as thermosetting phenol-formaldehyde and isocyanate are used in conjunction with wax and other additives to construct the mats (US EPA, 2002A). Typically, the ratio is 95% wood to 5% resins, wax, and other materials (Binggeli, 2008). Mechanical machines are used to orient correctly the wafer pieces during the mating phase. These machines are used to ensure perpendicular placement of the wafer pieces. The end result is a 3-to-5 layer mat panel that is not only stronger, but also more structurally sound than any other flakeboard product produced (Baker, 2002; Binggeli, 2008; US EPA, 2002A).

6.1.1.3 Particleboard

Particleboard is made from an assortment of wood particles, which include: wood shavings, flakes, wafers, chips, sawdust, strands, slivers, as well as wood wool (Binggeli, 2008; US EPA, 2002B). Depending on whether the wood is classified as face versus core, will play a role in particleboard construction (US EPA, 2002B). The exterior surface or face layer of particleboard is comprised of fine wood, while the interior layers are constructed from solid wood pieces (Tetlow, 2005; US EPA, 2002B). The construction of this board begins with wood particles entering the manufacturing facility for processing. The next step is the reduction stage. In this phase, various machines including: harmmermills, flakers, and refiners are used to both decrease particle size and ensure wood piece consistency and standardization. Once the wood is of the appropriate length, vibrating and gyratory screens are used to remove dirt as well as to separate fine materials from core materials. Both wood types are then sent through rotary dryers to reduce their moisture content (US EPA, 2002B).

After the drying phase, the exterior and interior materials are moved to blender machines where resins, wax, and other additives are added to the wood particles to create mats. The injection of wax and other additives is done not only to increase the panel's water resistant proprieties, but also to enhance its stability (Binggeli, 2008; CPA, 2008B; US EPA, 2002B). It should be noted that urea-formaldehyde is the typical resin used. In some instances phenol-formaldehyde can replace urea-formaldehyde as long as the mats being constructed are for exterior use only. Once the mats are formed, air currents along with forming heads are used to construct the multilayer particleboard (Tetlow, 2005; US EPA, 2002B). After the mats are layered they are moved to a hot press. At the hot press, resins within the mats are activated by the heat and the pressure (Binggeli, 2008; US EPA, 2002B). The temperature and time needed to construct these panels is 132^{o}C to 288^{o}C and 2.5 minutes (min) to 6 min, respectively (US EPA, 2002B). The end result is the bonding of the layers together to form a solid board (Binggeli, 2008; US EPA, 2002B). The last phase is the cutting, sanding, and trimming of the boards to the desired specification. With the completion of these steps, the boards are packaged and ready for shipment (US EPA, 2002B). The end result of this process is the production of panels that are not only extremely strong, but also water resistant (Binggeli, 2008).

6.2 Environmental Impacts of Composite Panels through their Lifecycle

The environmental impacts connected with composite panels were extremely difficult to ascertain due to a lack of literature (Rivela et al, 2007). Because no sources were dedicated towards composite panels and the environmental impacts connected with it, many generalizations were made. Some of these generalizations included: any virgin wood used in the manufacturing of composite panels came from harvested forests; clearcutting is the only extraction approach used in the removal of harvested trees; and the same type of environmental impacts arise no matter what the composite style and/or brand is. Numerous literary sources were relied on to identify specific stages of a panel's life where certain detrimental environmental impacts could arise. For instance, literature that discussed the techniques involved in harvesting wood exposed the harmful impacts connected with wood acquisition; while studies that compared and contrasted the environmental impacts connected with employing different types of materials were used to uncover the adverse impacts connected with wood utilized in the construction of buildings. Relying on a broad range of sources helped to uncover as many environmental impacts as possible.

6.2.1 Resource Extraction: Harvesting Impacts

6.2.1.1 Wood Harvesting Industry Management Improvements

Over the last few decades, great strides have been made in forest management to lessen the environmental impacts associated with wood harvesting. These changes have included: species modification, better wood fiber quality, greater resource efficiency, better forest usage, and stricter governmental regulations. The development of these progressive and environmentally friendly changes can be attributed to new techniques and technologies being adopted (Russelburg, 2006; Youngquist and Hamilton, 1999). Another approach taken to encourage appropriate forest growth, maintenance, and tree extraction has been sustainable forest management (The World Band, 2008). The philosophy of this concept is “to ensure that the goods and services derived from the forest meet present-day needs while at the same time securing their continued availability to long-term development” (FAO, 2007 pg.1). Wood certification has been yet another step implemented to lessen the impacts connected with wood harvesting. With wood certification, independent auditors evaluate the harvesting operations against standard environmental, social, and economic criteria. Assessment of these procedures is done to ensure that the management practices employed are environmentally friendly (CWC, 2008; Milani, 2005; The World Bank, 2008). Although wood certification is a step in the right direction, there are some downfalls with it. The fact that numerous certification programs exist with different evaluation standards, results in some certification programs being weaker than others. The evolutionary movement of forest management has played a role in the type and amount of environmental impacts that arise with wood usage (Youngquist and Hamilton, 1999). Even with these preventative measures, there are still a number of adverse environmental impacts.

6.2.1.2 Ecological Impacts of Harvesting

Even though a majority of the wood strands and fibers used to manufacture composite panels comes from wood waste/scraps, wood is still used. Therefore, it only makes sense to begin the environmental impacts section with a discussion about wood harvesting and the adverse impacts connected with this type of practice. Research has found that wood harvesting does lead to a number of adverse environmental impacts that can unfavorably affect the various components and processes found within a forest's ecosystem. Many of these damaging outcomes are a result of the clearcutting technique used to extract trees (Kimmins, 1997). Parts of the ecosystem that are affected include: climate and microclimate, soil, vegetation, wildlife, water and fish, carbon cycle, and the area's aesthetic value (Kimmins, 1997; Lang, 2002; Spong, 2007).

6.2.1.3 Climate and Microclimate

Forests play a critical role in both the hydrological cycle-- which is responsible for cloud formation and atmospheric humidity, and radiant energy balance-- which controls the air temperature. When large areas of forests are cleared, as in developing countries, both the hydrological cycle and the radiant energy balance are affected. The result of them being disturbed is changes in the local climate. In areas where clearcutting is at a much smaller scale, as in developed countries, regional climate changes tend to be absent (Kimmins, 1997).

Alterations in the ecosystem's microclimate represent yet another adverse outcome of wood harvesting. No matter how large or small the harvesting area is, microclimate change is inevitable. There are a number of factors that influence the microclimate of a forest floor. They include air temperature, humidity levels, wind speeds, and natural light infiltration. When an area is harvested, the microclimate is changed because the trees no longer protect the forest floor. Microclimates only return to their original state once new herbs and shrubs reestablish themselves into the area (Kimmins, 1997).

6.2.1.4 Soil

Soil is another component in the ecosystem that is negatively affected by wood harvesting (Kimmins, 1997; Lang, 2002; Spong, 2007). In uncovering the adverse impact clearcutting can play on soil, a number of factors need to be considered. These factors include knowledge about the ecosystem type (the level of elevation, the harvesting of flat or sloped land, and the soil and vegetation types that inhabit the area), harvesting equipment used, time of year, and the ability of the equipment operator. Knowing this information influences the type, amount, and area that will be affected (Kimmins, 1997). Two activities that negatively affect the soil are the construction and use of access roads as well as tree extraction (Kimmins, 1997; Spong, 2007). Common soil impacts that arise from this action include soil compaction, decreases in soil aeration and drainage, nutrient loss (initially after the clearcut), and soil disturbances, which can lead to soil instability and slope failures (for example landslides) (Kimmins, 1997; Lang, 2002; Spong, 2007). It should be noted that only years after a clearcut has occurred can soils begin to naturally regenerate on its own. This action increases soil nutrients and soil fertility. Soils can be renewed due to a reduction in the amount of plants and trees found within the area. Because nutrient uptake by trees and shrubs decreases due to less vegetation in the area, there is an increase in nutrient infiltration. This boost in soil nutrients occurs because of the increased level of decomposing wood debris found on the forest floor as a result of the clearcut (Kimmins, 1997).

6.2.1.5 Vegetation

An inevitable outcome of tree removal is alterations to the local plant community. When an area is clearcut, a number of changes happen to the plants and vegetation that live on the forest floor. For example, plants that require shaded environment become extremely stressed and will likely die when they are exposed to the open environment. With the loss of forest canopies comes the death of shade loving vegetation. The death of this vegetation leads to the invasion of new species in the area that begin to thrive in the new environment. Species disturbances and death are dependent on forest location (Kimmins, 1997). Harvesting done in northern forests tends to increase species diversity, while species loss is more problematic in tropical forests. A further factor that hurts forest vegetation is the creation and use of access roads (Kimmins, 1997; Spong, 2007). With the death of some species and the loss of other vegetation, the end result is alteration of the plant community's composition (Kimmins, 1997).

6.2.1.6 Wildlife

Wildlife is one aspect of the forest ecosystem that is most disrupted by clearcutting. Species survival depends on their environment. Clearcutting a forest changes accessibility of food, water, shelter, and breeding grounds. Animals living within a clearcut area either die because of inability to adjust to their new surroundings, relocate to a new area that is similar to their old habitat, or adapt to their new environment (Kimmins, 1997). Changes in the composition of the ecosystem are inevitable with clearcutting. These changes occur when the previous ecosystem is replaced by new networks of species that are more likely to thrive in the new environment. All wildlife (whether vertebrate or invertebrate species including microbes) are negatively affected by habitat disturbances and destruction of wood harvesting (Kimmins, 1997).

6.2.1.7 Water and Fish

Forest streams and rivers are radically changed when an area is harvested as well. Changes in water quality, quantity, and flow are common impacts. These water transformations emerge because of nearby land and soil alterations. The size of the watershed, the area being harvested, and the proximity of the watershed to the harvested area are all factors that influence the amount and type of impacts that arise. For instances the smaller the watershed, the greater the impact will be, and the larger the watershed, the lesser the impact will be. Water disturbances that arise include warming of the stream through increased natural sunlight exposure, loss of leaf litter, streambank instability, and finally sedimentation problems caused by road construction and use (Kimmins, 1997). As with wildlife, fish also depend on appropriate environmental conditions for their survival. When the characteristics of a stream or river are altered, fish abundance and reproduction abilities change. Once again, the harvesting's proximity to lake or river beds will influence the effect it has on the local fish that inhabit the watershed. Higher water temperatures and less leaf litter results in reduce fish reproduction. Any changes to the watershed can lead to significant impacts on the local environment, as in the case of wood harvesting and its effects on fish (Kimmins, 1997).

6.2.1.8 Carbon Cycle

Release of carbon into the atmosphere does occur when an area is clearcut. Most of the carbon discharged comes from humus and decomposing logs located on the forest floor (Kimmins, 1997; Natural Resources Canada, 2003). Even though a substantial amount of carbon is released, the planting of new trees allows for the recapture of this carbon (Kimmins, 1997). When harvested wood is made into structural materials, the CO2 that was captured by these trees is indefinitely stored within them. The ability for wood to sequester large amounts of CO2 results in a net removal of CO2 from the atmosphere (CWC; 2008; Kimmins, 1997; Natural Resources Canada, 2003).

6.2.1.9 Aesthetic Value

Harvesting also alters the visual appearance of the forests. When an area is clearcut, the beautiful trees and vegetation that once inhabited the area are replaced with a forested area that is patched with trees and empty fields. The barren look that usually results is unaesthetic to one's eyes and ruins the recreational atmosphere created by the forest (Kimmins, 1997).

6.2.2 Transportation and Manufacturing Impacts

The transportation of materials to and from the manufacturing facility is another point in a product's life where environmental burdens can arise. Trucks and trains, which rely on nonrenewable resources such as gas, diesel, and oil, for power generation transport the wood resources used for panel production from outside wood based businesses and bring them to composite panel manufacturers (Rivela et al, 2007; US EPA, 2002A; US EPA, 2002B; US EPA, 2002C). These vehicles cause serious environmental impacts including the extraction of natural resources, the processing of these resources into a useable fuel, and finally the release of greenhouse gases as a result of vehicle use (Boyle, 2003). These same impacts also arise when trucks, trains, and ships are used to transport finished panels to their final destination (Rivela et al, 2007). For the purpose of this paper, the emissions discharge from transportation vehicles will be the only impact examined.

Although limited literature exists regarding composite paneling and the environmental impacts that occur with its transportation, Rivela et al (2007) provide some insight and discussion on this issue. Even though the focus of the article was on lifecycle assessment of MDF, one section of this paper was devoted to the impacts connected with material transportation (Rivela et al, 2007). It is assumed that the same types of impacts will arise with OSB and particleboard. To determine the impacts MDF transportation has on the environment, this article examined the delivery routes of three different MDF manufacturers. From the data, five scenarios were created and evaluated. The main difference between each scenario was the distances MDF traveled (0, 200, 725, 2,000 and 10,030 kilometers (k m)) (Rivela et al, 2007). Knowing that trucks are the typical transportation vehicles used to deliver products, four out of the five hypothetical situations assumed trucking. In the transoceanic scenario a combination of both truck (30km) and ship (10,000km) transport was assessed (Rivela et al, 2007). After a detailed examination of the different scenarios, the article found that as the delivery distance increases, so too do the environmental impacts, except with the delivery of panels via ship. Data revealed that transoceanic trips have fewer environmental impacts than a truck that has a delivery route that is at least 725km. The report also found that human health, ecosystem quality, and resource depletion are all areas that are impacted by vehicle transportation. The authors did not explain how these areas were negatively disturbed; they just identified resource depletion as being the greatest impact followed by human health and then ecosystem quality (Rivela et al, 2007). Although vague in terms of the exact environmental impacts that arise, Rivela et al were able to provide useful information regarding the role a vehicle type plays on the environmental burdens that can transpire.

The various processes involved in composite paneling manufacture represent another key period in a panel's life where adverse environmental impacts can happen. These undesirable outcomes appear with the use of processing machines. The fact remains that these machines (debarkers, cutters, grinders, chippers, hammermills, flakers, refiners, waferizers, vibrating and gyratory screens, rotary predryers, single-stage and multi-stage tube dryers, conveyor dryers, blenders, steam-pressurized digesters, pressurized refiner chambers, hot presses, and sanders and trimmers) rely on natural resources such as gas, wood, oil, and diesel to function (US EPA, 2002A; US EPA, 2002B; US EPA, 2002C). With the consumption of fuel, comes the release of added emissions into the atmosphere. The pollutants discharged from these machines include particulate matter (PM), volatile organic compounds (VOCs), carbon monoxide (CO), CO2, and nitrogen oxides (NOx) (Rivela et al, 2007; US EPA, 2002A; US EPA, 2002B; US EPA, 2002C). When it comes to the amount and type of pollutants released, there are number of factors that influence the discharge. These include, "wood species, dryer temperature, fuel used … season of the year, time between logging and processing, chip storage time… type and amount of resin used to bind the wood fibers together… wood moisture content, wax and catalyst application rates, and press conditions" (US EPAB, 2002, pg. 3). Even with the best controls in place such as exhaust systems, VOC control technology, regenerative thermal oxidizers (RTOs), regenerative catalytic oxidizers (RCOs), and thermal catalytic oxidizers (TCOs), pollutants are still discharged (US EPA, 2002A; US EPA, 2002B; US EPA, 2002C). Some of the adverse outcomes that result are decreases in outdoor air quality leading to human respiratory problems and increases in greenhouse gases which can cause a rise in global temperatures (Rivela et al, 2007; Youngquist and Hamilton, 1999).

The use of adhesives also plays a role in the environmental impacts that crop up with panel processing. Although great strides have been taken over the last few years to reduce the environmental impacts connected with bonding resins, adverse impacts still occur (Yu and Crump, 1999). Once again, there are several factors that influence the amount and type of emission being released from these resins. These factors include:

> temperature, humidity, air movement over the panel surface, air change rate… the local formaldehyde concentration… wood species, moisture content of the wood flakes, the type and the chemical composition of the adhesive binder used, the additives (e.g. catalysts and formaldehyde scavengers) added, the arrangement of the multi-layer board, the surface treatment, the density of the board and the manufacturing conditions (Yu and Crump, 1999, pg. 282).

Unfortunately, the major outcome of injecting bonding resins during panel construction is the release of formaldehyde into the atmosphere (Binggeli, 2008; Yu and Crump, 1999). The type of adhesive used influences the amount of formaldehyde emissions being discharged (Yu and Crump, 1999). Urea-formaldehyde is the most commonly used adhesive. This resin is favored over alternative adhesives because of its price. With such an inexpensive price, the level of formaldehyde being released is greater compared to other adhesives used to make the same number of composite panels (Binggeli, 2008). To lessen the amount of formaldehyde escaping into the environment alternative adhesives have been created that release less formaldehyde. Furthermore, improvements in adhesives and injection techniques have been able to reduce formaldehyde emissions by approximately 90% (Binggeli, 2008; CPA, 2008B; Tetlow, 2005; Yu and Crump, 1999). New resins created include phenol-formaldehyde, melamine-formaldehyde, and methylene diphenyl diisocyanate. Although different in chemical composition, their function is the same- to bond wood particles together (Binggeli, 2008).

Problems with formaldehyde exposure are the adverse impacts it has on human health. When concentration levels are higher than 0.1parts per million (ppm) side effects that can appear include watery eyes, wheezing/coughing, chest tightness, burning eyes/nose/throat (Australian Government, 2007; NSC, 2008). These adverse side effects should never result from composite panels that are injected with formaldehyde, since not enough of this chemical is used in these panels. Although the indoor air quality may have slightly higher formaldehyde levels then rooms constructed with wallboard, these levels are believed to be so low that no ill effects should arise. In terms of health problems associated with formaldehyde exposure during composite panel manufacturing, once again there should be no adverse health impacts since breathing masks and proper venting systems are in place to ensure workers are not breathing in this harmful toxin (Emery, no date). Even though researchers believe there are no serious health impacts associated with formaldehyde exposure during composite panel manufacturing and indoor use, these opinions could always change. Research devoted to the health impacts associated with the level (amount of exposure) and time (short versus long term) of formaldehyde exposure is extremely limited.

Currently available information about long-term formaldehyde exposure comes from wildlife research. The effects this toxin has on wildlife include decreased lifespan, reproductive problems, increased risk of cancer, and changes in animals' appearance, and behavior (Australian Government, 2007). Because of these damaging health impacts caution is needed in human uses of formaldehyde since long-term health effects on other animals are now known.

6.2.3 Use and Disposal Impacts

In terms of environmental burdens associated with panel use, the release of formaldehyde emissions are once again a problem (Binggeli, 2008). As already discussed in the previous section, long-term exposure to formaldehyde can lead to the emergence of harmful health effects for both humans and animals alike. However, it is believed that formaldehyde levels in composite panels are so low that they will not cause these adverse health problems (Australian Government, 2007; Yu and Crump, 1999). Because formaldehyde exposure has already been discussed, the remaining part of this section will be dedicated towards composite panel disposal. When it comes to the end-life of panels, there are a number of disposal options available such as incineration, recycling, and/or landfilling. The amount of information dedicated towards composite panel disposal is extremely limited. Literature that does exist focuses on the disposal impacts of pure wood waste and not on composite panel waste (Smith, 2004). The environmental impacts of pure wood waste may be completely different from the disposal impacts of composite panel waste (Smith, 2004).

When a panel reaches its end life, its condition plays a significant role in how it will be managed. Incineration, landfilling, and recycling are three different disposal options. With each of these options there are a number of drawbacks, especially when these panels are contaminated with binding additives and decorative finishes (Youngquist and Hamilton, 1999). In terms of incineration, the adverse environmental impacts that arise with this disposal option are the toxic emissions (PM, VOC, CO2, NO_x, and formaldehyde) that are released into the atmosphere (Smith, 2004; US EPA, 1998; Youngquist and Hamilton, 1999). The release of these toxins into the environment reduces air quality, which negatively affects the health (respiratory problems, coughing, and watery eyes) of both humans and animals alike (Youngquist and Hamilton, 1999).

With regards to landfilling composite panels, the environmental impacts that can arise include the occupation of valuable space, the contamination of water, and once again the release of emissions because of the resins used to construct the panels and the paints, veneers, laminates, wallpaper, and so forth to finish the panels (Youngquist and Hamilton, 1999). When composite panels are untreated and not contaminated with overlays or paints, recycling is yet another disposal option that exists. Unfortunately, because many of these panels are saturated with other contaminates (adhesives and fire/mold resistant toxins) the number of reuse options for this recovered wood is limited. The only recycling option that does exist is to chop these panels into tiny wood chips. These chips can then be used to make mulch and compost (Yeoman, 2007; Youngquist and Hamilton, 1999). The environmental concerns that comes to light with panel recycling is the reliance on fuels to run the machines, the release of greenhouse gas emissions from the machines, and the release of toxic preservatives and adhesives (Youngquist and Hamilton, 1999). Once again, one sees the same pattern where product disposal creates adverse impacts. Although the literature was scarce in terms of the environmental impacts connected with panel disposal, it became evident that problems do exist and will continue to occur unless changes are made to current disposal practices.

6.3 Environmental Advantages of Composite Paneling over Alternative Materials

Limited research has been devoted towards the advantages and disadvantages of using composite panels over alternative products. As a result, literature that focuses on wood was used because the main material used in composite panel construction is wood and information regarding environmental impacts of wood is abundant.

One study particularly helpful in highlighting the environmental effects of wood was prepared in 2000 by the ATHENA Sustainable Materials Institute. The Canadian Wood Council commissioned this study (Zylkowski, 2002). The focus of this research was to identify and then to compare the environmental impacts that arise with the use of wood, steel, or concrete as the main building material in the construction of a house (Trusty and Meil, no date; Zylkowski, 2002). A lifecycle analysis approach was used to identify the environmental impacts that transpire. The lifecycle stages examined included "resource procurement, manufacturing, on-site construction, building service life, and decommissioning at the end of the useful life of the building" (Zylkowski, 2002, pg. 1.7). This study evaluated a standard 2,400 square foot (ft^2) house located in Toronto, Ontario under three different material conditions (Trusty and Meil, no date). In the first model, the dominant structural material used was wood. The house was framed with lumber and I-joists were used for the floor and roof. The second model was a steel house. This house was designed using light-gauge steel as framing material for both the floors and walls. The third model was a concrete house. This house used insulated concrete forms for the walls and composite concrete for the floor (Zylkowski, 2002). The environmental impact areas studied were the embodied energy of the material, global warming potential, air and water toxicity, weighted resource use, and solid waste (Trusty and Meil, no date; Zylkowski, 2002). Running these house designs through different lifecycle calculators, it was determined that "construction with wood uses less energy, represents less global warming potential, has fewer impacts on air and water, and represents less weighted resource use" (Zylkowski, 2002, pg. 1.8). The results from this study illustrates the environmental advantage wood has over concrete and steel. However, some caution should be given since other materials were used in the construction of each house (Trusty and Meil, no date). Although this study only examined the lifecycle impacts of wood, it assumed that a similar lifecycle finding would arise with composite panels since on average 85%-95% of these panels are constructed from wood particles (Binggeli, 2008; Tetlow, 2005). Some further advantages of using wood based products include the renewability of wood, the environmentally benign nature of wood as a material, and finally the biodegradability of wood (Sedjo, 1996).

6.4 Characteristics of Composite Panels

6.4.1 Financial Cost

Engineered wood is sold in a number of different types and sizes depending on what features are wanted. Composite wood panels are cheaper than solid wood panels (Binggeli, 2008, CPA, 2008A). This difference in price is because composite panels are constructed primarily from recycled and recovered wood particles. The supply and demand patterns of the area will influence panel pricing (Binggeli, 2008). Panel prices vary with panel dimensions, wood waste used, number of mat layers employed, and finally the addition of various materials to increase panel rating (Binggeli, 2008; CPA, 2008B). In determining the prices of MDF, OSB, and particleboard, visits to building supply stores were carried out to ascertain current prices. Discussions with store employees along with product examination helped to identify not only product type, but also product features. After evaluation of all three panel types, particleboard was found to be the most expensive panel, followed by OSB and then MDF. In terms of the composite panel price range, panels start as low as $6.64 and finish as high as $31.21Canadian (CDN). Not only are these panels sold in different universal sizes (see the thickness table as well as the width and length table 6.1 and table 6.2), but they can also be custom ordered as well (Home Depot, 2008B; Lowes, 2008B).

Table 6.1 A list of thickness that composite panels are sold in (Binggeli 2008; NRHA & HCI, 2000)

Standard Composite Paneling Thickness (in inches)
1/4
3/8
7/16
15/32
1/2
5/8
3/4
1 1/8

Table 6.2 A list of widths and lengths that standard composite panels are sold in (Binggeli, 2008; NRHA &HCI, 2000)

Standard Composite Paneling Widths (in feet)	Standard Composite Paneling Lengths (in feet)
2	4
2	6
2	8
2	12
4	4
4	8
4	12
8	8
8	12
8	24

6.4.2 Installation, Maintenance, Product Durability, and Availability

Knowledge about a product's user friendliness is a key feature that can either hurt or help a product's acceptance and use within the construction industry (Binggeli, 2008; House Flipping Helper, 2008). There is limited information identifying the strengths and weaknesses of installing composite panels as an interior wall. Information that does exist focuses on the installation impacts that arise with using composite panels as either exterior walls or floor construction (Russelburg, 2006).

Knowing the steps involved in hanging composite panels as an interior wall is important in determining the workability of this material. One piece of literature particularly informative about the step-by-step processes, which are similar to those used to hang wallboard was an article published by a home improvement website. This article explained how easy composite panel installation is, as long as the correct tools are used. Below is a list of the main steps involved:

1. Determine the number of composite panels needed
2. Cut the panels to the appropriate sizes using a power saw
3. Fasten the panels with either fasteners or shank nails to the wood or metal framing studs of the panels (fewer fasteners/shank nails are needed when the panels are cut with tongue and grove connections)

4. When installing the panels remember to leave 3mm gap between each panel and along all door and window openings, in order for the panel to have enough room to expand
5. Apply compound to where fasteners and joints are showing (if there is no veneer covering)
6. Wait before sanding the compound down
7. Apply another coat of compound to the same area
8. Once again wait before sanding the area
9. Apply one more layer of compound to where the joints and fasteners are
10. Paint or wallpaper the wall if desired (Home Improvement Tips, 2008).

Although the installation steps of both wallboard and composite board are basically the same, composite panel is more difficult to install for two reasons. First, composite panels weigh more than wallboard. The extra weight of these panels not only makes them more difficult to handle, but also more cumbersome to install (NRHA & HCI. 2000). Second, composite panels are more difficult to cut. Because these boards are made from layers of compressed wood, special tools are needed to cut through these panels. The only tools strong enough to slice these boards are power tools. The fact that wallboard can be cut with a knife while composite panels have to be sliced with a power tool leads to additional installation time making this material more costly to install initially (Home Improvement Tips, 2008).

Even though the initial installation of composite panels is more time consuming the probability of issues arising once this paneling is in place is low. The fact that composite panels are less susceptible to panel shrinkage or swelling reduces the overall number of callbacks or additional installation time needed to correct the problem (Binggeli, 2008; CPA, 2008A; Russelburg, 2006).

The panels are durable, extremely sturdy and more dimensionally stable compared to most other panel type products found on the market today (Binggeli, 2008). To ensure these panels have high durability ratings, a number of preservative treatments are typically added to the panels to protect the wood against decay. These preservative treatments involve chemicals being impregnated into the wood to prevent fungi growth and insect decay. The panels will experience less structural deterioration since chemical controls are in place to protect these panels against outside elements (Zylkowski, 2002). In regards to product availability, most building supply stores sell an assortment of composite panel products. Their availability in the market place represents one more factor that makes this product a favorable wallboard substitute.

6.4.3 Aesthetic Quality

The aesthetic quality of MDF, OSB, and particleboard depends on whether the panels are left in their natural condition or are infused with decorative overlays. When these panels are left with a wood based exterior, a warm natural appearance is projected. The rustic look of these panels is very attractive to some individuals. However, the panel seams are more visually apparent with this paneling option than with gypsum wallboard (CPA, no date). In instances where a woodsy appearance is not wanted a number of decorative finishes exist depending on the amount of money and time one is willing to spend. When looking at panel finishes, two options exist- panels sold with an exterior finish or panels sold without a finish (Binggeli, 2008). In cases where panels are sold with finished overlays, various decorative laminates exist such as thermally fused melamines, decorative metals, heat transfer finishes, engineered wood veneers, thermoformable vinyls, powder coatings, decorative foils and lacquers (CPA, no date, pg. 2). Unique technologies are used to create each of these panel overlays that not only lead to spectacular finishes, but also improve panel performance (stronger and greater protection against decay) (CPA, no date). When composite paneling is sold with no finish three decorating options exist- paint, wallpapere or veneer covering. With all three of these options, panels must already be installed and extra steps, such as panel sanding and cleaning must be completed before these finishes can be applied (Binggeli, 2008). Like wallboard, composite panels have a number of decorative finishes available and as a result their aesthetic quality can be high.

6.4.4 Composite Panel Rating

When one decides whether composite panel is the right interior wall choice, a number of factors need to be considered. Knowing the fire rating of each panel helps to select the appropriate panel for the area. There are three classes, in which a material can be rated A, B, and C (Rose, 2002; Tetlow, 2005). The structure's use will influence the rating class needed for the area (Rose, 2002). In terms of OSB, MDF, and particleboard, Class C is the fire rating most of these panels fall under (Rose, 2002; Tetlow, 2005). What this means is that the flame spread index of these panels is from 76 to 200 and takes less than half an hour to burn. Although composite panel rating is low, most interior wall materials have just as low a rating. The reason why a class C rating is acceptable is that most building code regulations only require a class C fire rated material in construction of most homes and structures (APA, 2005A). Hospitals and institutions represent buildings where a higher fire rated material, is required (Rose, 2002). In some instances a composite panel's fire rating can be as high as A, if special fire-retardant additives are injected into the wood (Rose, 2002; Tetlow, 2005). When these panels have a special fire-retardant coating, the flame spread rating can go all the way down to 25 or less and take two hours to burn (Rose, 2002). The end result is a more fire-resistant panel. With the addition of these additives is an increase in price (Tetlow, 2005). When decorative finishes are applied to class A panels, it is vital that these finishes are fire retardant, in order to maintain the fire rating level of the product (Rose, 2002).

Knowing whether the panels are protected against moisture is another important evaluation factor. Composite panels are primarily made from organic materials. As a result these panels run the risk of being permanently damaged by water and moisture. To prevent this from happening, improved adhesive technology has made these panels more water and moisture resistant. Two moisture resistant bonds that have successfully prevented panel deterioration are melamine-fortified urea formaldehyde and phenol-formaldehyde resins (Tetlow, 2005). These resins have improved a panel's ability to cope with water and moisture by improving the thickness swelling and linear expansion of the board (ability to expand when expose to water/moisture and shrink back to normal size when no longer exposed to these element without comprising the paneling) (Tetlow, 2005, pg. 6). Adding decorative layers to these panels only further improves the water and moisture resistant properties of these boards (Tetlow, 2005). Sound deadening properties are dependent on a panel's thickness and whether extra materials are added to reduce noise transmission. As in the case of wallboard, the more expensive the composite panel is, the more sound absorptive it is, and the higher the moisture, water, and fire rating ability will be (NRHA & HCI. 2000).

6.4.5 Recyclability

The reuse and recycling of composite board is relatively low due to the wood being contaminated by bonding and chemical adhesives. The recycling market is underdeveloped because the technology needed to handle contaminated wood is still in its infancy (Youngquist & Hamilton, 1999)

When boards are recycled, the recovered material can only be used for boiler biomass fuel, wood floor filler, and landscape mulch (Smith, 2004; Tchobanoglous, 2002) However, most is used for boiler fuel (MassDEP, 2005).

6.4.6 Product System Vulnerability to Failure

As discussed in the previous chapter, product vulnerability is an important issue to consider when one decides whether a particular product is a good wall option. If the system is vulnerable to failure, a decrease in product acceptance is likely to occur since there is a higher risk associated with the use of this product. Just like gypsum wallboard, composite panels have a number of areas susceptible to system collapse. Areas where problems could arise include harvesting, limited recycled wood waste, transportation issues, manufacturing trouble, equipment/machinery failure and human error. This list is very similar to the gypsum wallboard list. The only difference centers on wood choice, whether it is harvested wood or wood waste versus raw mineral collection. Although these areas were identified as potential target zones where system failure could happen, the probability of it actually occurring is low. It is considered low because composite panel production and its use indicate this. It is a well-established system with limited problems happening over the years. The fact that a thorough understanding exists regarding the operation of this system helps one to differentiate the implementation of good changes from problematic changes.

6.5 Alternative Wall Products Considered but did not Make the Cut

Cement board and plywood were two alternative wall materials also considered to be potentially suitable replacements. However, after doing a comprehensive background check on these materials, it was determined that these materials would not be good interior wall materials.

6.5.1.1 Cement Board

True cement based products have typically not been used in the construction of interior walls. In the last few years, however, a greater understanding of this material and its properties has led to the creation of cement board. This product has become an attractive wallboard replacement option because it is not only extremely durable and versatile, but it is also mold and freeze/thaw resistant, non-combustible, a good insulator, and water durable (CGC, 2008). Even with these benefits, a number of environmental drawbacks exist with its manufacture and use that make it an undesirable wall material.

Cement board is made from a number of raw minerals including iron, aluminum, calcium, and silicon (Binggeli, 2008). Problems that arise with the use of so many raw minerals are the number of mines created and the distances these materials have to travel for processing. The adverse environmental impacts identified with cement board creation include:

- Habitat disturbance by the creation of mines and roadway systems
- Extraction and use of nonrenewable resources such as coal, nuclear, gas, diesel, oil not only to power the building and all the processing machines, but also the transport vehicles
- Burning of these nonrenewable resources which leads to the release of air pollutants including: CO_2, sulphur dioxide, NO_x, sulphuric acid, and hydrogen sulfide
- Consumption of large quantities of water to wash the raw minerals off
- Creation of and discharge of dust which negatively impacts human health by causing allergic skin reactions, eye irritations, and breathing difficulties (Binggeli, 2008, pg. 31)

Researchers have discovered that 5% of all human-made CO2 released into the atmosphere comes from cement fabrication. For every ton of cement produced 1.25 tons of CO2 is released into the atmosphere. Despite attempts to reduce these emission levels by improving the cement manufacturing process, limited advancement has been made (Binggeli, 2008). Limited information exists on the benefits and limitations of cement board installation and use as an interior wall structure. Discussion with local hardware store employees provided information needed to decide whether cement board would be an appropriate alternative interior wall material. Common problems identified by these employees included: difficulty in cutting, high wastage since any crack in the panels means it can no longer be installed, extreme weight and therefore difficult to maneuver and install, expensive cost, and difficulty in painting and/or wallpapering (Home Depot Employees, 2008; Home Hardware Employee, 2008). Although cement board was seen as a possible replacement for wallboard during the initial stages of this research, the in-depth review revealed a different story. It became clear that replacing wallboard with this product would not be environmentally advantageous.

6.5.1.2 Plywood with Decorative Overlay

Another product that was initially considered to be an excellent wallboard substitute was finished plywood. Plywood is primarily comprised of thin layers of wood veneers that are bonded together with heat and adhesive glue to form a panel (Backer, 2002; Binggeli, 2008). The solid plywood panels constructed are not only strong, durable, and versatile, but also good for the environment (renewable resource). Because plywood is made out of thin cut wood veneer pieces, the weight per panel is extremely low. Being such a lightweight panel not only makes it easier to maneuver, but also easier to install (Binggeli, 2008; Home Depot Employees, 2008). The reason why plywood was originally thought of as a suitable interior wall option is its similarity to composite paneling. These two products are almost identical in terms of material composition, manufacturing processes, installation techniques, and disposal options. As a result, their product evaluations are also extremely similar. The same kinds of benefits and limitations identified with composite paneling were also identified with plywood paneling (Baker, 2002; Binggeli, 2008; Home Depot Employees, 2008).

Initially plywood paneling looked like a good substitute, but after further review a significant drawback was uncovered that made it a less attractive option: its price (Home Depot Employees, 2008). Plywood is a more expensive option because these panels are made from pure wood veneers rather than mixed wood waste (Backer, 2002; Binggeli, 2008). Because almost any type of wood species can be used to make plywood, the price per panel varies considerably depending on the wood type and chemical treatments used. At the cheaper end of the plywood price ladder are panels that sell for $11.00 per panel while more expensive panels can go as high as $143.00 per panel (Goosebay Inc., 2008; Home Depot Employees, 2008; Rona, 2008). In comparing these prices to wallboard and composite board, the cost factor for plywood is a lot higher. The fact that plywood and composite paneling are almost identical on every level except price makes it highly unlikely that plywood would be favored over the cheaper composite paneling. This difference in price is why plywood was abandoned as a potentially feasible interior wall option.

6.6 Summary

After a detailed examination of alternative wall materials, it has been determined that the only wall options that could feasibly replace wallboard, are composite panels. Although nine types of composite panels exist, a review of the literature and a discussion with individuals in the construction industry identified MDF, OSB, and particleboard as being three panels that could realistically replace wallboard in the future. These three composite panels were selected because they were similar to wallboard in terms of function, cost, and installation requirements. Like wallboard, there are also a number of environmental drawbacks associated with using these panels. Instead of adverse problems arising during panel creation as in the case of wallboard, most of the environmental issues occur during their end-life. The biggest advantage, but also disadvantage is the natural resource used to construct these panels. The recycling of wood is an environmental benefit, but the high combustibility of wood makes these panels more susceptible to fire unless fire retardants are added. With the addition of chemical injections, not only is there an increase in adverse impacts to the environment, but disposal of these panels becomes a problem. The trade-off between composite panels and wallboard is at what stage in the panel's life these problems occur. See chapter 8 for a more detailed comparison between composite panels and gypsum wallboard using the sustainable IWM criteria for alternative material.

Chapter 7 Current End-life Management of Wallboard in Southern Ontario

7.1 Reuse Options for Clean Wallboard Waste

When wallboard is discarded, the condition and size of the scraps play a role in what management options are available. Donation and resale options are two common reuse avenues employed with clean wallboard scraps. Although reuse is an excellent management option, unfortunately not all clean wallboard waste is redirected down this route. Depending on scrap size influences the management path these scraps follow. In cases where the wallboard is at least half the size of the original sheet, donation and resale are two viable options. In instances where scrap size is smaller than half size sheets, product recycling or final disposal are the only two options left (Marvin, 2000). Product reuse is not feasible for these wallboard scraps due to the extra time needed to tape and to nail the smaller scraps together (Johnston and Mincks, 1992; Recycling Council of Ontario, 2005). When wallboard scraps are the appropriate donation size, nonprofit organizations like Habitat for Humanity either use these pieces in the construction of new homes or sell them at their resale store to make money for their charity (Marvin, 2000). Discussion with the Waterloo Habitat for Humanity Resale Store revealed that wallboard sheets are not a commonly donated item. Furthermore, when contractors were asked if they ever donated wallboard scraps, the answer was no (Greyhound Employee, 2009; Keating, 2009; Rosmar Employee, 2009).

7.2 Reuse Options for Contaminated Wallboard Waste (Hazardous and Nonhazardous)

There are no viable reuse options for reusing wallboard waste that is contaminated. Wallboard scraps that are contaminated with such things as paint, nails, screws, and adhesive glues are not reused because these pieces are viewed as unclean and therefore useless. As a result of this attitude, landfilling this waste is the most favored management option employed (Recycling Council of Ontario, 2005).

7.3 Recycling Action Taken for Clean and Contaminated Wallboard Waste

A variety of different products can be created from recycled wallboard waste. In situations where wallboard waste is mostly clean and there is no wallboard recycling facility in the area, wood chippers can be used to breakdown the wallboard scraps (Block, 2000; White and Burger, 1993). A magnetic head can be added to the chipping machine to remove any nails or screws that may be in the boards (Block, 2000). When chipping machines are used, the recovered end product is small wallboard chips that are less then ½-inch (.in) in size (Block, 2000; Marvin, 2000; White and Burger, 1993). Because this recycling process is unable to separate the paper from the gypsum core, the created chips contain both face paper as well as gypsum minerals. Because these chips contain some paper, reuse options for these chips are limited to uses such as animal/livestock bedding and agricultural fertilizer (Block, 2000)

In instances where wallboard recycling facilities exist, the philosophy of breaking down the wallboard scraps is still followed, but instead of gypsum chips, it is turned into fine gypsum powder. In Southern Ontario, three wallboard recyclers have been identified. New West Gypsum (NWG) is recognized as the best recycler because wallboard recycling is this company's specialty. They have the area, proper machinery, and techniques to recycle most wallboard waste including wet wallboard (McCamley, 2004; Musick, 1992; WRAP, no date). With the other two facilities the processing techniques is less established, although they can deal with clean and contaminated wallboard waste. The only type of contaminated waste these recycling facilities cannot handle is dirt covered and hazardous filled (lead paint and/or asbestos) wallboard. Depicted in table 7.1 are answers to a number of questions posed to each recycling facilities (New West Gypsum Employee, 2009; Sittler, 2009; Waring, 2009).

Table 7.1 The questions and responses to the operation of various recycling facilities in Southern Ontario

Questions	**Interviewees**		
	New West Gypsum	Sittler Environmental Inc.	Try Recycling
Disposal practices for clean wallboard waste	Recycle	Recycle	Recycle
Disposal practices for contaminated wallboard waste	Recycle unless contaminated with dirt and/or asbestos	Recycle unless contaminated with hazardous material	Recycle unless contaminated with asbestos or other hazardous materials
Average distance wallboard waste travels for disposal	40 kilometers – Toronto area	Waterloo Region	50 kilometers – immediate London area
Furthest distance average wallboard waste travels for disposal	500 kilometers – once a month loads are brought in from Ottawa due to LEED projects		200 kilometers – 20 to 30% of wallboard waste will come from the Golden Horseshoe
Tipping fee for discarded wallboard waste	$57.50 per tonne, but rates may change depending on volume and customer	$64.00 per tonne but rates may change depending on volume and customer	$72.00 per tonnes, but rates may change depending on volume and customer
Percentage of wallboard waste entering the facility that is clean	98% – most wallboard entering the facility comes from new construction projects or nearby wallboard manufacturers	Majority	60% to 70% - some of the wallboard is from demolition and renovation project, but most comes from new construction
Differences in processing price depending on the condition	No difference in price	No difference in price	No difference in price

The processing technique used to recycle wallboard waste differs slightly from one recycler to the next. When wallboard waste is brought to NWG, hand sorters as well as forklifts are used to separate wallboard scraps from other contaminates such as wood, garbage, or metal waste. Once properly separated, both clean and contaminated wallboard waste is placed on a conveyor belt. This belt passes through a hopper machine and through the magnetic separator where ferrous metal pieces that may exist in the panels, are removed. The board is then transported to the processing unit where the paper backing is separated from the gypsum board. Ninety-nine percent of the paper backing is separated from gypsum's core. The core is processed into a powder form, which is then shipped to a nearby wallboard manufacturer (Certainteed Gypsum) for the manufacturing of new wallboard. The paper is trucked to a nearby farm where it is used for animal bedding. What makes NWG different from other recyclers is their ability to handle new wallboard sheets that have not made it through the drying stage in the wallboard manufacturing process (New West Gypsum Employee, 2009).

At Sittler, the first step involves separating wallboard waste from other construction waste materials. The separated wallboard is then either ground or crushed, depending on what process is implemented. Two different wallboard recycling techniques are being used in order to determine, which approach provides the better end product. As the wallboard sheets are sent either through the crusher or through the grinder, they pass through a magnetic separator where any magnetic metal is removed. Once the wallboard exits, it is sent to the screening plant where a trommel screen is used to separate the paper from the gypsum minerals and any metal that still remains. Try Recycling uses the same grinding process as Sittler for recycled wallboard, but their sellable product is different. Sittler uses the recovered minerals in compost piles and as a soil neutralizer. Try Recycling sells the waste paper as an industrial absorbal that is used as a bulking agent when hazardous waste is transported. The recycled gypsum is sold as an agricultural fertilizer (Sittler, 2009; Waring, 2009).

In the past, wallboard manufacturers have been hesitant to use recycled wallboard waste in the manufacture of new wallboard because of how inexpensive raw gypsum is (Laquata, no date; Musick, 1992). The wallboard industry has started to realize that wallboard recycling is one step that must be taken to help reduce the environmental impacts associated with this product. By recycling wallboard and reusing the minerals in the production of new wallboard, there is less demand on the environment due to a reduced need of raw gypsum (Anonymous, 2003; New West Gypsum Employee, 2009). In Southern

Ontario, NWG is the only wallboard recycler who sells their recovered gypsum to a wallboard manufacturer, Certainteed. NWG technology allows 20% of new wallboard to be made from their recovered gypsum (New West Gypsum Employee, 2009). Wallboard manufacturers only permit a certain percentage of recycled gypsum in the production of their new panels in order to maintain the same quality of board (Anonymous, 2003; McCamley, 2004; Musick, 1992; WRAP, no date).

The other wallboard recyclers in Southern Ontario sell recycled gypsum for different land applications including composting agent and soil fertilizer (Sittler, 2009; Waring, 2009). Recycled gypsum is an excellent bulking agent for compost because of its ability to absorb excess moisture. It also adds extra calcium, sulfur, and carbon to the area, as well as absorbs odors that may be permeating from the pile. Whenever gypsum minerals are used as a composting additive, extensive monitoring of the pile's temperature, moisture content, and oxygen levels must be executed to ensure anaerobic decomposition is not happening (Marvin, 2000).

When gypsum minerals are added to agricultural fields, they act like a fertilizer and encourage planet growth (Carr and Munn, 2001; Marvin, 2000; Nature's Way Resources, no date; White and Burger, 1993; Wolkowski, 2003). The benefits connected with gypsum mineral application is limited to certain types of soils (hardpan subsoil clay and arid) and crops (alliums, almonds, barley, citrus, coffee, corn, clover, desert salt grass, grapes, lawns, marsh vegetation, papaw, peanuts, potatoes, strawberries, tomatoes, raspberries, sugarcane, wheat, wheatgrass) (Nature's Way Resources, no date pgs. 9-11). Although using recycled gypsum wallboard waste can lead to positive crop production, some concern exists with its use as a soil fertilizer. Some of the apprehension centers on such things as: how much should be applied to the fields, how can this mineral be uniformly spread, how can the mineral stay on the field and not be blown away when there is wind, how hazardous is the mineral to the environment, and finally how likely can this mineral contaminate drinking water (White and Burger, 1993; Wolkowski, 2003). Over the years, improvements in wallboard waste recovery and the application of gypsum minerals onto fields has alleviated some of these concerns. Using gypsum pellets instead of powder not only results in a more uniform application, but it also reduces the chances of these pallets being blown away by the wind (Wolkowski, 2003). The amount of gypsum that can be added to the soil will be dependent on the crop and the soil type. A common recommendation to follow is no more than 2 tons/acre on sandy soil and no more than 5 tons/acre on medium-density soil. With regards to the environmental impacts connected with gypsum minerals, plants and animals have shown no ill effect when used as a land applicator as long as the minerals are clean from hazardous material (Blcok, 2000; Wolkowski, 2003). The final concern centers on the mineral's ability to penetrate groundwater and cause contamination. Research done by White and Burger (1993) was able to resolve this concern. Their research involved taking soil samples, in which gypsum minerals were being used as a soil fertilizer and measuring the amount of heavy metals found within the soil. The heavy metals they measured included arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. These heavy metals were chosen because they have the greatest potential to contaminate groundwater. The data revealed that the eight heavy metals measured were below the detection limits of the instrument. Therefore, there is no need to worry about groundwater contamination when gypsum minerals are used as a soil fertilizer (White and Burger 1993).

Even though recovered wallboard waste in Southern Ontario is generally used in the manufacture of new wallboard or as a soil fertilizer, these are not the only mineral reuse options available. Other options that exist include:

- Athletic field marker – grinding wallboard scraps into a fine white powder that can then be applied to fields as a field marker (Marvin, 2000; Nature's Way Resources, no date)
- Animal and livestock bedding – combining ground drywall with wood shaving and paper to make animal/livestock bedding. The benefits of using ground wallboard is its ability to reduce foot problems and increases udder health of cows (Marvin, 2000)
- Cement production – 10% of new cement can be made from recycled gypsum as long as there is no paper backing. Gypsum is used to control the set time in cement production (Marvin, 2000; Nature's Way Resources, no date).

- Flea powder – over 90% of the inert ingredient in flea powder can be made from recycled gypsum (Nature's Way Resources, no date)
- Grease absorbent – excellent absorbent product for small oil spills the only downfall is the visibility of this absorbent (Marvin, 2000; Nature's Way Resources, no date)
- Odour reducers – the chemical properties of gypsum allow this material to be an excellent odor absorber (Marvin, 2000)
- Water treatment – adding gypsum minerals to the water helps the suspended particles settle to the bottom (Marvin, 2000).

7.4 Contaminated Management Options when there is no Wallboard Recycling Facility

In instances where wallboard waste being produced is contaminated and there are no recycling facilities in the nearby area, limited management options exist. Under these circumstances, the only available options are to either landfill or incinerate (Carr and Munn, 2001; Johnston and Mincks, 1992). The implementation of either of these waste management options not only results in permanent raw material loss, but can also adversely affect the environment (Peng et al, 1995). These negative outcomes are why every attempt should be made to prevent wallboard waste from ending up in landfills or being used as a source of energy for incinerators.

7.5 Summary

Condition, size, and local area are all factors that play a significant role in the disposal options available for wallboard waste. In cases where the wallboard waste is clean and the sheet sizes are greater than half its original size, reuse is possible. When reuse is not a viable option, wallboard recycling is possible, but depends on the local area. In the case of Southern Ontario, three wallboard recycling facilities exist, but they are located in populated areas. As a result, some areas in Southern Ontario are too isolated to bring their wallboard waste to these facilities due to long travel distances. In situations like this, chipping machines can be used to breakdown the clean wallboard waste. Although this technique is primitive, the wallboard is recycled and the chipped product can be used for livestock bedding and agricultural fertilizer. When isolated areas have contaminated wallboard waste, the only feasible option currently is to transport it to a landfill site. Although recycling facilities do exist in Southern Ontario, and chipping machines can be used to recycle wallboard waste, most wallboard is still being landfilled because it is still the easiest and cheapest disposal option available today.

Chapter 8: Discussion of Recommended Options and their Evaluation

8.1 Background

Avoidance is oftentimes the most favored approach in dealing with any type of problem. When avoidance is favored over a proactive approach, it often leads to a continuation and enlargement of the problem. Consideration is usually given to a problem when it gets out of hand. When this happens, the only way to deal with it is to face it head on and develop realistic solutions (Pettinger, 2007).

In evaluating the current gypsum wallboard situation, it is evident that an avoidance based approach has been taken. Discussion with waste coordinators in addition to a review of the literature has identified gypsum wallboard as a difficult material to manage (Arsernault, 2009; Binggeli, 2008; McCamley, 2004; Recycling Council of Ontario, 2005; Saotome, 2007). This waste is problematic because of the construction industry’s unwillingness to adopt better disposal procedures. Lack of education about the different disposal paths that can be used for wallboard is an additional factor that has hindered wallboard management (Arsernault, 2009; Waring, 2009). The amount of resources, understanding, and time dedicated towards developing solutions to improve its handling and its disposal has been absent. This avoidance based approach to wallboard management can no longer be an option. The following section evaluates different wallboard management options.

Examination of the current situation indicates that there are options available. The problem with having so many choices is differentiating between options that are feasible and those that are not. When developing options for wallboard waste, every attempt has been made to suggest options that are realistically feasible to adopt. The generic categories of alternative wall materials and change in practices were created to help organize the options. For background information regarding gypsum wallboard and alternative materials see Chapters 5 and 6 respectively. The following sections are general discussions of the various options recommended and the potential benefits and limitations with their use.

8.2 Justification for Option Ordering

A great deal of thought has been given to the ordering of these options. It was determined that the best way to arrange these options were to organize them based on the waste management hierarchy of refuse/replace, reduce, reuse, and recycle. Although product refusal was not an option discussed, product replacement was. As a result, product refusal was substituted by product replacement. The hierarchy of principles these options were categorized under include: alternative wall material (product replacement) and change in practices (reduce/reuse/recycle). Discussion of each option was based on what was learned through the literature review, what was observed during the observation sessions, and what information was collected during the semi-structured interviews. Appendices E, F G, H, and I contain a detailed discussion on the information collected during the observation sessions and learned through the interviews. A detailed discussion of each option was vital in providing the necessary information needed to evaluate the feasibility of each option. At the end of the *Alternative Wall Materials* category and *Change and Practices* category, a sustainable integrated waste management (IWM) criteria set was used to rate each option. The sustainable IWM criteria for evaluating alternative materials were employed to rate options that focused on material changes while the sustainable IWM criteria for evaluating change in practices were used to rate options that centered on behavioral changes.

8.3 Alternative Wall Materials

8.3.1 Leaving the Current Gypsum Wallboard Situation Alone

8.3.1.1 <u>Benefits and Limitations with Using Wallboard</u>

As already discussed in chapter 5 section 5.2.1 and validated by the interviewees (Appendices F, H, and I), wallboard is an excellent wall material. Price makes it a particularly attractive product. The unlimited supply of natural and synthetic gypsum minerals has kept purchasing cost low in comparison to other wall materials. Additional characteristics that make wallboard great include its light weight, strength, ease of installation, natural fire resistance, relative durability, availability, range of styles and features, versatility, and finally good insulation proprieties (Binggeli, 2008; Greyhound Employee, 2009; Fryett, 2009; Keating, 2009; Sittinger and Sittinger, 2005; SRM Architect Employee, 2009). A further benefit, which sets it apart from other wall materials, is the ease with which it satisfies building code requirements (Gere, 2009; Fryett, 2009, SRM Architect Employee, 2009). Because wallboard is the normal interior wall material used in wall creation, most interior wall requirements specified by the Ontario Building Code (OBC) are based on walls constructed from wallboard. When architects need to satisfy building code requirements, approval is not a problem as long as they select wallboard that meets the standards required for the particular structure (see Appendix F) (Fryett, 2009).

From a construction standpoint wallboard is one of, if not, the best wall material option to use (Gere, 2009; Fryett, 2009; SRM Employee, 2009). From an environmental viewpoint, the amount and severity of adverse impacts connected with wallboard creation, use, and disposal make it a less attractive wall material. The reliance on raw gypsum leads to the disturbance of natural areas to obtain this pure mineral. Some of the main problems with this mining include alteration to the natural habitat, acid mine drainage, soil disturbances, and pollution in the form of air, land, water, and noise (Cottard, 2001; Ecosystem Restoration, 2004). Consumption of natural resources to power transport vehicles and run processing machines is another point in the wallboard's life that adversely impacts the environment. Not only is more mining and processing done to convert natural resources into useable fuels (oil, gas, and diesel), but when these fuels are consumed by vehicles and machines they release enormous amount of greenhouse gases. On average, gypsum minerals travel 230 kilometers (km) (one-way) for processing. This demonstrates that a significant amount of natural resources are consumed before the panel is even created (New West Gypsum, 2003; Recycling Council of Ontario, 2005). Although other environmental impacts arise throughout the sheet's life, the last serious one involves its landfilling. When wallboard is landfilled not only does it consume landfill space, but it also produces substantial amounts of hydrogen sulphide gas under aerobic conditions and leaches metallic sulphide into the groundwater (Arsenault, 2009; Binggeli, 2008; Marvin, 2000; McCamley, 2004; Musick, 1992; New West Gypsum Employee, 2009; Saotome, 2007). From discussions with individuals who work in the construction industry, it is evident (see Appendices H and I) that little awareness exists regarding the damaging environmental impacts connected with wallboard use and disposal (Gere, 2009; Greyhound Employee, 2009; Keating, 2009; Rosmar Employee, 2009). This lack of education can be attributed to the waste management industry. Interviews with individuals in this sector revealed awareness about the damaging adverse impacts connected with landfilling wallboard (see Appendix G). Unfortunately, because the waste sector has no obligation to educate the construction industry about the harmful impacts connected with the disposal of wallboard, the construction industry ignorance about the problems associated with landfilling wallboard will continue to exist. Chapter 5 section: 5.4 *Environmental Impacts of Wallboard through its Lifecycle* has a more detailed discussion regarding the lifecycle of wallboard and the environmental impacts connected with it.

Health problems are yet another downfall associated with using wallboard (see section 5.4). A substantial amount of dust is created during wallboard installation, demolition, and recycling, which can lead to skin, eye, and respiratory irritations (Binggeli, 2008). When wallboard is landfilled a new set of adverse health impacts can arise. The release of hydrogen sulphide gas is one problem highlighted in the literature and cited by waste processors (Arsenault, 2009; Marvin, 2000; McCamley, 2004; Musick, 1992; NWG Employee, 2009; Saotome, 2007). If individuals or animals are exposed to this gas for long periods of time and/or in large quantities, it can lead to unconsciousness and even death. The contamination of groundwater from the leaching of metallic sulphide can also lead to human death, if too much contaminated water is ingested (Marvin, 2000; McCamley, 2004; Musick, 1992; Saotome, 2007). Finally, although wallboard is naturally fire resistant, in some instances chemical adhesives are added to increase the panel's fire, mold, and moisture resistant properties. The addition of these chemicals can reduce the indoor air quality, which can lead to breathing difficulties and skin irritations for the individuals working in this environment (Youngquist and Hamilton, 1999).

Wallboard waste is ranked only behind wood and concrete in regards to the total amount of waste discarded at a project site (McCamley, 2004). On new project sites, 27% of the overall waste produced (by volume) is comprised of wallboard scraps while at demolition sites it is 21% (Recycling Council of Ontario, 2005). It is also estimated that 17% of the global wallboard market ends up as scrap drywall and 64% of all wallboard waste comes from new construction (Binggeli, 2008; Saotome, 2007). What these numbers indicate is that a significant amount of wallboard waste is being produced on construction sites, and that a majority of this waste is uncontaminated. Because most of the discarded wallboard waste is clean, alternative wallboard management options need to be implemented other then landfilling. Identification and adoption of waste reduction initiatives should be the first step taken. From literature studies and discussion with waste processors, a lot of wallboard waste is created due to wasteful practices (Arsenault, 2009; NWG Employee, 2009; Recycling Council of Ontario, 2009; Try Recycling, 2009). If the construction industry was given more encouragement and resources to improve upon these poor practices and implement better waste preventative measures, wallboard waste totals could be reduced. Furthermore, if better waste diversions programs were in place to redirect wallboard waste away from landfills and instead redirect it towards reuse and recycling options, this would be another positive step in improving the management of this waste. Although the construction industry has started to make improvements in how their industry operates, they still have a far way to go.

Wallboard waste tends not to be recycled because of a number of false beliefs. Arguments that have appeared in the literature include ones assuming that the high moisture content of wallboard panels makes recycling impossible; the recycling technology is unable to completely remove the paper backing resulting in unclean gypsum minerals; and there is no market for recovered gypsum minerals (Recycling Council of Ontario, 2005; Saotome, 2007). These beliefs are incorrect. Wallboard is a highly recyclable product. The problem is that some individuals within the construction industry are unaware that wallboard can be recycled, or for that matter that wallboard recyclers exist in Ontario (see Appendix I). Other reasons cited why wallboard waste is not recycled include longer hauling distance increases transportation costs for the construction industry; lack of education by crew members to collect drywall off-cuts; regulation loopholes and a lack of enforcement with the regulations in place; constant competition in tipping fees with landfill facilities encouraging this industry to continue to use landfills; discouragement for wallboard recyclers to establish facilities in

Southern Ontario because waste is allowed to be transported to United States for disposal; and finally wallboard is such an inexpensive product that it is often considered not worth recycling (NWG Employee, 2009; RIS International, Ltd., 2005; Recycling Council of Ontario, 2005; Saotome, 2007; Sittler Employee, 2009; Waring, 2009; Waring, 2009). From this list of obstacles it is clear that there is a disconnect in communication, knowledge, and capabilities between the Ontario government, the construction industry, and the recycling industry.

Landfilling is not the only final disposal option available for wallboard waste. Incineration and ocean dumping are two additional methods that have been used to manage this waste, but unfortunately, the environmental impacts connected with these disposal options make them just as unattractive as landfilling (see section 5.6.2).

The best disposal option after reuse is to recycle wallboard waste, from an environmental standpoint (see section 5.6.1). Within the last decade great strides in technology have allowed the recycling industry to recycle almost any type of wallboard. The only wallboard that cannot be handled is hazardous wallboard, which has lead paint and asbestos associated with it (NWG Employee, 2009; Sittler Employee, 2009; Waring, 2009). Everything that is recovered from the recycling process has a market. The paper can be used as an industrial absorbent or for animal bedding. The raw gypsum can be mixed with virgin gypsum to make new wallboard sheets, or it can be spread on agriculture fields and act as a soil fertilizer (Marvin, 2000; Nature's Way Resources, no date; NWG Employee, 2009; Sittler, 2009; Waring, 2009). With recycling, not only is this process recovering minerals that would otherwise be lost forever if landfilled, but these recovered materials are being turned into sellable products.

Although wallboard is an excellent wall material, the major downfall is its management. Due to poor management, the environment is adversely being affected which in turn is having damaging impacts on human and animal health. If greater waste reduction initiatives were implemented and there were improvements in the management of wallboard waste, wallboard would be an even better material. It is only a matter of time before the construction industry eliminates these poor practices and replaces them with more environmentally responsible actions.

8.3.2 Composite Panels

8.3.2.1 Benefits and Limitations with Using Composite Panels

After a review of the literature and discussions with members of the construction industry (see section 6.1.1), it was determined that the only realistic replacement option for wallboard, is composite paneling (Fryett, 2009; SRM Architect Employee, 2009). After further review, medium-density fiberboard (MDF), oriented strandboard (OSB), and particleboard were the three sub-products under composite paneling that were studied because they were comparable to wallboard in terms of function, cost, and installation requirements (CPA, no date; Binggeli, 2008; McKeever, 1997). Although three different types of composite panels were recommended, in this discussion these panels have been grouped together under the general category of composite panels. Discussion about the benefits and limitations with using composites panels is general and applies to all three panel types. Merging the three panels into one category was done due to a lack of information on each individual panel. Chapter 6 contains more information on this as well as a review on other wall materials examined.

Characteristics of composite paneling that make it an appealing wall material and a suitable replacement for wallboard include: low purchase price if the panels are untreated, availability at any building supply store, high durability if preservative treatments are added, relative ease of installation as long as the proper tools are used, fairly lightweight, availability in a broad range of styles and features, and aesthetical appeal (see section 6.4) (Binggeli, 2008; CPA, no date; Zylkowski, 2002). Because the majority of these panels are made from wood, they have a much lower fire resistant rating than wallboard. However, with the injection of chemical resins, these panels can achieve fire ratings just as high as wallboard. The only problem is that the panel price increases (Fryett, 2009; Rose, 2002; Tetlow, 2005).

Composite paneling from a manufacturing standpoint is an environmentally attractive material because it is primarily made from recycled wood waste and furthermore, tree age and tree species play no role in panel production (APA, 2005B). However just like wallboard, composite panels also have a number of adverse ecological impacts connected with them. Although wood waste is the typical material that comprises these panels, in instances when wood waste is not available, harvested wood is used. Unfortunately, a number of adverse environmental impacts arise with using harvested wood, such as changes to climate and microclimate, soil disturbance, vegetation loss, wildlife resettlement and death, reductions in water quality resulting in a decreased fish population, alteration to the carbon cycle, and alterations to the natural environment that make it no longer aesthetically appealing (Kimmins, 1997; Lang, 2002; Spong, 2007). The consumption of nonrenewable resources to power transport vehicles and to run the manufacturing warehouse, leads to the release of enormous amounts of greenhouse gases (Boyle, 2003). The use of adhesives to bond wood particles together results in the discharge of toxic pollutants. These pollutants have been found to have detrimental impacts on wildlife (decreased lifespan, reproductive problems, increased risk of cancer, and changes in animals' appearance and behavior) (Australian Government, 2007). Although other adverse impacts exist, landfilling of composite panels is a major issue. When these panels are injected with chemicals they are unable to be recycled and as a consequence, these panels tend to be landfilled. Problems highlighted with this disposal option are the occupation of valuable land space, contamination of water, and the release of emissions from the resins used to construct the panels (Youngquist and Hamilton, 1999). A more detailed discussion regarding the lifecycle of composite panels and the environmental impacts connected with it is given in chapter 6 section: 6.2 *Environmental Impacts of Composite Panels through its Lifecycle*.

The injection of various resins into these panels is a major concern on the impact it will have on human health. Because many of these panels contain some formaldehyde within them, symptoms such as watery eyes, wheezing/coughing, chest tightness, burning eyes/nose/throat are side effects that can emerge if concentration levels are greater than 0.1 parts per million (ppm) (Australian Government, 2007; NSC, 2008). Although formaldehyde concentration levels should never get this high, the amount of research regarding long-term human health impacts associated with this toxin in the indoor environmental is limited (see sections 6.2.2 and 6.4.4) (Youngquist and Hamilton, 1999).

When individuals in the construction industry were asked if composite paneling could substitute wallboard as an interior wall option, most interviewees said yes (see Appendices F and I) (Gere, 2009; Greyhound Employee, 2009; Fryett, 2009; Keating, 2009; SRM Employee, 2009). However a number of concerns were raised. Is there enough wood waste to produce composite panels at a volume that gypsum wallboard is currently being consumed at? How would the Ontario Building Code (OBC) react to these panels? What extra steps would need to be taken to satisfy these regulations? Finally, would extra costs be incurred from using this product over wallboard (Gere, 2009; Fryett, 2009; SRM Employee, 2009)? The structure being constructed will determine if these panels meet building code standards. Because these panels are identified as a combustible material, using composite panels in structures that prohibit the use of combustible materials is a problem. Although solutions exist, such as injecting panels with fire retardants to make them noncombustible or putting sprinklers systems in the building, all of these actions cost extra money. Once chemicals are added to composite panels their price dramatically increases. Therefore, it is important to know whether the structure being built can use combustible or noncombustible materials since it will greatly influence panel pricing (Greyhound Employee, 2009; SRM Employee, 2009; Fryett, 2009).

Wallboard is easier to install than composite paneling (Gere, 2009; Greyhound Employee, 2009; Keating, 2009; Rosmar, 2009; SRM Employee, 2009). Although wallboard and composite panel use the same installation techniques, composite panel is more difficult to hang not only because it weighs more, but power tools are needed to cut the panels. Therefore, the initial installation of composite panels is more time consuming. However, the likelihood of issues arising once these panels are hung is unlikely since they are less susceptible to panel shrinkage and swelling in comparison to wallboard (see section 6.4.2).

Incineration, landfilling, and recycling are the three disposal options for unwanted composite paneling (see section 6.2.3 and Appendix G). The level of contamination will influence the disposal path it takes. Panels that are chemically contaminated are either incinerated or landfilled. The problem with these two disposal approaches is the release of toxic emissions into the atmosphere (Yeoman, 2007; Youngquist and Hamilton, 1999). Under certain circumstances, contaminated composite panels are recycled. When this happens, it usually occurs when they are mistakenly mixed with clean wood waste (Arsenault, 2009; Sittler, 2009). Contaminated panels are currently unable to be recycled due to a lack of technology to remove adhesive glues and/or chemicals additives from the waste product. The only way these panels are ever going to be recycled is if improvements in recycling techniques allow the extractions of these chemical additives. Until then, composite panels will continue to either be incinerated or landfilled. In the case of untreated panels, recycling is possible. There are a number of products made from this recovered wood including wood floor filler, landscape mulch, landfill cover, sewage sludge additive, and in some cases the manufacturing of new composite paneling (Sittler, 2009; Waring 2009)

The literature and interviews indicate that there are advantages and disadvantages with using these panels as an interior wall option. Although composite panels are made from recycled wood waste, these panels are unable to be recycled if contaminated. This is a significant drawback, which has serious consequences for how these panels are going to be managed if they are to replace gypsum wallboard in the future.

8.3.3 Evaluation of Gypsum Wallboard and Composite Panels Using the Sustainable IWM Criteria Set

A product's characteristics will have a significant impact on how a product is rated in the sustainable IWM criteria set. The different features that can be added to wallboard and composite panels makes it difficult to rate these products generically since different panel characteristics will lead to different ratings. Therefore, ratings were based on the most common wallboard and composite panel characteristics sold today. Discussion with the construction industry and a review of the literature was able to identify these characteristics (see table 8.1). Two different types of composite panels were rated in order to show the rating differences that exist between treated and untreated panels. Furthermore, ratings were based on these products being landfilled unless stated otherwise. The ratings themselves were based on what was learned through the research. It should be noted that many generalizations were made when rating these two products (some of the wood used in the manufacturing of composite panels is virgin; all wallboard is manufactured using raw gypsum; untreated wallboard has no man-made chemicals within it; average travel distance for recycling facilities is further than 30 kilometers; and all wallboard is landfilled). Once again, in Chapter 3 section 3.4.1 is a list of the criteria items used for evaluation. The definition of each item in the criteria set, as well as what a positive/negative rating indicates for each criteria item, is discussed. The ratings of alternative materials using the sustainable IWM criteria can be seen in table 8.2

Table 8.1 The width and treated/untreated features of wallboard and composite panel

Features	Wallboard	Composite Panel A	Composite Panel B
Width	1/2-inch	1/2-inch	1/2-inch
Treated/untreated	Untreated	Untreated	Treated

Table 8.2 Evaluation of alternative materials using the sustainable IWM criteria framework

A Lifecycle Effect of the Prevailing Impacts that arise with Certain Wall Materials											
Evaluation Tools (Criteria)	**Alternative Wall Material Options**										
	Gypsum Wallboard				**Composite Panel A**			**Composite Panel B**			
	Creation	**Use**	**Disposal**	**Section(s) of Where it was Discussed in Thesis**	**Creation**	**Use**	**Disposal**	**Creation**	**Use**	**Disposal**	**Section(s) of Where it was Discussed in Thesis**
Environmental Impacts with Current Technique				See Chapters 5 and 8 sections: 5.4 *Environmental Impacts of Wallboard Through its Lifecycle;* 8.3.1.1 *Benefits and Limitations with Using Wallboard* and Appendix G section: *Knowledge Acquisition and Personal Opinions*							See Chapters 6 and 8 sections: 6.2 *Environmental Impacts of Composite Panels Through its Lifecycle* and 8.3.2.1 *Benefits and Limitations with Using Composite Panels*
• *Land*	---	0	--		--	0	--	--	0	--	
• *Water*	--	0	--		--	0	--	--	0	--	
• *Air*	---	--	--		--	-	-	---	---	---	
• *Habitat disturbance and modification*	---	0	-		--	0	-	--	0	-	
• *Species disturbance and biodiversity loss*	---	0	-		--	0	-	--	0	-	
*Environmental Impacts with Anticipated Improvements**				See Chapter 5 sections: 5.4 *Environmental Impacts of Wallboard Through its Lifecycle*; 5.6.1 *Waste Minimization: Reduce, Reuse, Recycle* and							See Chapter 6 section: 6.2 *Environmental Impacts of Composite Panels Through its Lifecycle*
• *Land*	--	0	-		-	0	-	-	0	-	
• *Water*	-	0	0		-	0	0	-	0	0	
	-	-	-		-	-	-	-	-	-	

• *Air*	--	0	-	Appendix G section: *Information Regarding Facility Practices*	-	0	-	-	0	-	
• *Habitat disturbance and modification*	--	0	-		-	0	-	-	0	-	
• *Species disturbance and biodiversity loss*											
Health Impacts	---	--	---	See Chapter 8 section: 8.3.1.1 *Benefits and Limitations with Using Wallboard*	--	-	--	---	---	---	See Chapter 8 section: 8.3.2.1 *Benefits and Limitations with Using Composite Panels*
Energy Consumption	---	N/A	-	See Chapter 5 section: 5.4.2 *Transportation and Manufacturing Costs*	---	N/A	-	---	N/A	-	See Chapter 6 section: 6.2.2 *Transportation and Manufacturing Impacts*
Material Composition	-	N/A	N/A	See Chapter 5 section: 5.1.1 *Background on Gypsum*	++	N/A	N/A	++	N/A	N/A	See Chapter 6 sections: 6.1.1 *Wood Composite Panels*
Resource Availability	+++	N/A	N/A	See Chapter 5 sections: 5.1.1 *Background on Gypsum* and 5.1.2 *Gypsum Mineral Use*	+	N/A	N/A	+	N/A	N/A	See Chapter 6 section: 6.2.1.1 *Harvesting Industry Management Improvements*
Travel Distance	---	++	++	See Chapters 5 and 8 sections: 5.2.1 *Creation of Gypsum Wallboard and its Benefits;* 5.4.2 *Transportation and Manufacturing Costs* and 8.3.1.1 *Benefits and Limitations with Using Wallboard*	---	++	++	---	++	++	See Chapters 6 sections: 6.2.2 *Transportation and Manufacturing Impacts* and 6.4.2 *Installation, Maintenance, Product Durability, and Availability*
Product Functionality				See Chapters 5 and 8 sections: 5.2.1 *Creation of Gypsum Wallboard and its Benefits*; 8.3.1.1 *Benefits and Limitations with Using Wallboard;* Appendix F section:							See Chapter 6 and 8 sections: 6.4.2 *Installation, Maintenance, Product Durability, and Availability*; 6.4.3 *Aesthetic Quality;*8.3.2.1 *Benefits and Limitations with Using*
• *Durability*	N/A	-	N/A		N/A	++	N/A	N/A	++	N/A	
• *Aesthetic Appeal*	N/A	+++	N/A		N/A	+	N/A	N/A	+	N/A	
• *Maintenance ease*	N/A	++	N/A		N/A	++	N/A	N/A	++	N/A	

• *Installation ease*	N/A	+++	N/A	*Similarities*; and Appendix I section: *Fact Finding and Information Driven Questions*	N/A	+	N/A	N/A	+	N/A	*Composite Panels* and Appendix F sections: *Similarities* and *Differences* and Appendix I section: *Opinion Based Questions*
Product Rating • *Insulation* • *Noise Resistant* • *Fire Resistant* • *Mold Resistant* • *Moisture Resistant*	 N/A N/A N/A N/A N/A	 + - - -- --	 N/A N/A N/A N/A N/A	See Chapters 5 and 8 sections: 5.2.1 *Creation of Gypsum Wallboard and its Benefits;* 8.3.1.1 *Benefits and Limitations with Using Wallboard* and Appendix F section: *Similarities*	 N/A N/A N/A N/A N/A	 INA - --- --- ---	 N/A N/A N/A N/A N/A	 N/A N/A N/A N/A N/A	 INA - +++ +++ +++	 N/A N/A N/A N/A N/A	See Chapters 6 and 8 section: 6.4.4 *Composite Panel Rating*; 8.3.2.1 *Benefits and Limitations with Using Composite Panels* and Appendix F section: *Similarities*
Product Availability	N/A	+++	N/A	See Chapter 5 section: 5.2.1 *Creation of Gypsum Wallboard and Its Benefits*	N/A	+++	N/A	N/A	+++	N/A	See Chapter 6 section: 6.4.2 *Installation, Maintenance, Product Durability, and Availability*
Affordability	N/A	+++	N/A	See Chapter 5 section: 5.2.1 *Creation of gypsum Wallboard and Its Benefits*	N/A	++	N/A	N/A	---	N/A	See Chapter 6 section: 6.4.1 *Financial Cost*
Stakeholder Attitudes	N/A	+++	N/A	See Appendix F section: *Similarities*; Appendix H section: *Fact Finding and Information and Information Driven Questions* and Appendix I section: *Fact Finding and Information and Information Driven Questions*	N/A	+	N/A	N/A	+	N/A	See Appendix F section: *Similarities*; Appendix H section: *Opinion Based Questions* and Appendix I section: *Opinion Based Questions*
Stakeholder Participation	-	--	---	See Chapter 8 section: 8.3.1.1 *Benefits and*	-	--	---	-	--	---	See Chapter 8 section: 8.3.2.1 *Benefits and*

				Limitation with Using Wallboard Appendix G section: *Knowledge Acquisition and Personal Opinions*							*Limitations with Using Composite Panels*
Education	N/A	-	---	See Chapters 5 and 8 sections: 5.4.3 *Landfilling Wallboard*; 5.6.1 *Waste Minimization: Reduce, Reuse, Recycle* 8.3.1.1 *Benefits and Limitation with Using Wallboard* and Appendix G sections: *Knowledge Acquisition and Personal Opinions* and *Alternative Material Consideration*	N/A	-	---	N/A	-	---	See Appendix G sections: *Knowledge Acquisition and Personal Opinions* and *Alternative Material Consideration*
Employment	+++	++	++	Primary areas of employment: mining, vehicle transportation, manufacturing, installation, and disposal	+	+	++	+	+	++	Primary areas of employment: wood harvesting, vehicle transportation, manufacturing, installation, and disposal
System Vulnerability	+++	++	++	See Chapter 5 section: 5.5 *Product Vulnerability*	+	+	++	+	+	++	See Chapter 6 section: 6.4.6 *Product Vulnerability*
Product Uncertainty	+	N/A	N/A	See Chapter 5section 5.2.1 *Creation of Gypsum Wallboard and its Benefits*	+	N/A	N/A	---	N/A	N/A	See Chapters 6 and 8 sections: 6.2.2 *Transportation and Manufacturing Impacts;* and 8.3.2.1 *Benefits and Limitations with Using Composite Panels*
Regulations	N/A	N/A	++	See Chapter 4 section: 4.5 *Ontario Regulations Pertaining to CRD*	N/A	N/A	++	N/A	N/A	++	See Chapter 4 section: 4.5 *Ontario Regulations Pertaining to CRD Waste*

				Waste							
Enforcement	N/A	N/A	---	See Chapters 4 and 8 sections: 4.5.1 *3R's Regulations*; 8.3.1.1 *Benefits and Limitation with Using Wallboard* and Appendix G section: *Knowledge Acquisition and Personal Opinions*	N/A	N/A	---	N/A	N/A	---	See Chapters 4 and 8 sections: 4.5.1 *3R's Regulations*; 8.3.1.1 *Benefits and Limitation with Using Wallboard* and Appendix G section: *Knowledge Acquisition and Personal Opinions*
Product Donation	N/A	N/A	+	See Chapter 7 section: 7.1 *Reuse Options for Clean Wallboard Waste*	N/A	N/A	+	N/A	N/A	---	- can only be donated if clean (Habitat For Humanity Store)
Donation Restrictions	N/A	N/A	--	See Chapter 7 section: 7.1 *Reuse Options for Clean Wallboard Waste*	N/A	N/A	+	N/A	N/A	N/A	-must be clean
Service Availability	N/A	N/A	++	See Chapter 5 sections: 5.8.1*Obstacles Preventing Recycling of Wallboard in Ontario* and Appendix G sections: *Information Regarding Facility Practices* and *Alternative Material Consideration*	N/A	N/A	++	N/A	N/A	---	See Appendix G sections: *Information Regarding Facility Practices* and *Alternative Material Consideration*
Material Breakdown	N/A	N/A	---	See Chapter 8 section: 8.3.4 *Concluding Remarks and Recommendations on Gypsum Wallboard and Composite Panels*	N/A	N/A	+++	N/A	N/A	++	See Chapter 8 section: 8.3.4 *Concluding Remarks and Recommendations on Gypsum Wallboard and Composite Panels*
End Life of Product Management • *Reduce* • *Reuse*	 N/A N/A	 0 --	 --- ---	See Chapters 5 and 8 sections: 5.6.1 *Waste Minimization: Reduce, Reuse, and Recycle*; 8.3.1.1 *Benefits and Limitation with Using Wallboard*; Appendix G	 N/A N/A	 0 --	 --- ---	 N/A N/A	 0 --	 --- ---	See Chapter 6 section: 6.4.5 *Recyclability* and Appendix G sections: *Information Regarding Facility Practices* and *Alternative Material Consideration*

• *Recycle*	N/A	N/A	--	sections: *Information Regarding Facility Practices* and *Alternative Material Consideration*	N/A	N/A	--	N/A	N/A	---	
Future Consideration	---	0	---	Rating based on all gypsum wallboard information and if current practices were the same	-	0	-	---	-	---	Rating based on all composite panel information and if current practices were the same
Holistic Understanding	+	N/A	--	See Chapter 5 section: 5.5 *Product Vulnerability*	+	N/A	--	+	N/A	---	See Chapter 6 section: 6.4.6 *Product Vulnerability*

* The anticipated improvements for wallboard are that with time wallboard waste will be recycled, a greater percentage of new wallboard will be made from the recycled wallboard waste, and the chemicals injected into the board will be environmentally better. The anticipated improvements for composite panels are that eventually the waste will be recycled, new composite panels will be made from recycled waste, and the chemicals injected into the panels will be environmentally better.

Key: --- = extremely negative --= negative - = somewhat negative
0 = neutral + = somewhat positive ++ = positive +++ = extremely positive
N/A = Not Applicable INA = Information not Available

8.3.4 Concluding Remarks and Recommendations on Gypsum Wallboard and Composite Panels

After a detailed examination of gypsum wallboard and composite panels (treated and untreated), it is clear that a number of benefits and limitations exist with each. In determining whether composite board is a suitable replacement for gypsum wallboard, a comparison has been done between the two products to ascertain where the differences were and how significant these discrepancies were. A lifecycle approach (creation, use, and disposal) was taken to determine the various impacts of each product. The information acquired from each lifecycle has been evaluated using the sustainable IWM criteria set. By rating each option against the same criteria set, it is possible to determine which wall material option is most desirable and feasible for interior wall use in Southern Ontario. Although product ratings are identical in a number of categories (human health impacts, energy consumption, travel distance, maintenance ease, stakeholder participation, education, regulations and enforcements, and service availability) some significant differences do exist.

Material composition is one area where these two products did differ (see table 8.2). Composite panels are primarily made from wood, which is a renewable resource while wallboard is principally made from gypsum minerals, which is a nonrenewable resource. This difference results in the environmental edge going towards composite panels since most composite panels are made from recycled material. Furthermore, when virgin wood is used this resource is potentially renewable and the ecological impacts connected with wood harvesting are less detrimental to the environment in comparison to mining (see sections 5.4 and 6.2) (Binggeli, 2008; Panagapko, 2006; Sedjo, 1996). The question then becomes whether there is enough wood waste and/or harvested wood to meet current wallboard volumes. Although composite panels are made from a renewable resource, if there is not a sufficient quantity of wood to satisfy the demand level, this alternative wall material is an impractical substitution.

Another difference is the technique used for resource collection. In terms of composite panels, most wood either comes from recycled or recovered wood waste (Binggeli, 2008). On the other hand, most wallboard is made from virgin gypsum mineral that is extracted from isolated mines (Panagapko, 2006; Sittinger and Sittinger, 2005). The difference between using a recycled resource versus a virgin resource is the amount of environmental damage that will transpire. With the recycling of wood waste less environmental damage occurs because the resources already exist and therefore the natural habitat is not disturbed. When virgin gypsum is used to manufacture wallboard, natural areas are disrupted to acquire this raw resource (see section 5.4.1). This action therefore has a greater amount of adverse environmental impacts. In terms of resource collection the advantage goes again to composite panels.

There are many reasons why wallboard is an attractive wall material with one of the biggest being its ability to satisfy building code requirements (see section 6.4.4 and Appendix F). Architects and builders have a greater difficultly demonstrating to building code officials that composite panels are a safe and acceptable wall option. Because most building codes do not recognize composite panels as a wall option, most of the construction industry is less inclined to deal with the extra hassle and time it would take to get approval. A further drawback is the added expense associated with getting these panels fire resistant. Untreated composite panels are identified as a combustible material and therefore using these panels is severely restricted. Construction projects that would permit the use of untreated composite panels are residential projects. The beauty of wallboard is that it is naturally fire retardant and it can be used in many structures before extra fire retardant material needs to be added. The only way composite panels can easily satisfy building code regulations is if they are chemically treated. However, as noted above with the injection of chemicals, not only is there a greater amount of adverse impact affecting the environment, but panel disposal becomes more difficult (see composite panel B ratings; table 8.2) (Gere, 2009; Fryett, 2009, SRM Architect Employee, 2009).

A further benefit of using wallboard is its ability to be recycled once fire additives have been injected into it while a recurring theme that kept emerging in the literature is the inability to reuse and recycle composite panels that are injected with chemical adhesives (see sections 5.6.1 and 6.4.5, Chapter 7, and Appendix G). When wallboard panels are injected with certain materials to increase their resistant properties, recycling these panels is not a problem. With composite panels any additives that are injected in the panel results in immediate landfill/incineration disposal at the end of its end life. Unfortunately, with the implementation of either of these disposal techniques permanent loss of an otherwise recoverable material happens (Cheremisinoff, 2003; Dijkgraaf and Vollebergh, 2004; Peng et al, 1995). The only types of composite panels that can be recycled are untreated ones. However, if composite panels are to replace wallboard, a substantial amount of these panels would need to be injected with chemical additives. Because the technology has yet to be developed, recycling of these panels currently is impossible. Consequently, significant amounts of wood resources would be lost due to these panels being landfilled and/or incinerated instead of recycled.

There are always going to be trade-offs when comparisons are made between two different materials. In the case of these two products, it is no different. With wallboard, a greater number of adverse environmental impacts arise with panel creation, but installation, cost, familiarity, natural fire resistance, and recycling capabilities are all other aspects of this product that make it a superior wall material to composite panels. On the other hand with composite panels, fewer initial environmental impacts arise with its creation, but use and disposal become an issue. With untreated panels, recycling is possible but building use is severely restricted due to building code regulations. With treated panels, recycling is impossible but these panels can easily satisfy building code requirements. The question then becomes which one is better? The answer is a combination of both. Below is a list of recommendations that should be implemented.

- Wallboard should continue to be used, but that better waste prevention and diversion techniques should be implemented to lessen the adverse environmental impacts connected with its creation, use and disposal (see section 8.4 for further discussion).
- Untreated composite panels should be used as an alternative interior wall option in the building of residential homes.
- More research and technology should be devoted to developing recycling techniques that can handle treated composite panels.

8.4 Change in Practices

8.4.1 Background

After evaluation of alternative materials, it has been determined that wallboard is still the best interior wall option today. Currently, wallboard is not being managed appropriately (see section 5.4.3, 5.8.1 and Appendix G). If better management occurred through the adoption of more waste preventative strategies and enhanced disposal practices, wallboard would be an even better wall material option. Therefore, the remainder of this thesis is dedicated to discussion regarding feasible behaviors individuals and organization in Southern Ontario could adopt to improve wallboard management. Each behavior recommended is evaluated using the change in practice sustainable IWM criteria set. Once again, in Chapter 3 section 3.4.2 is a list of the criteria items used for evaluation, the definition of each item in the criteria set, as well as what a positive/negative rating indicates for each criteria item.

Discussion of waste minimization strategies have been broken down into two sections including general and product specific. Under the general category (design, pre-construction, and construction), the discussion revolves around waste reductions methods that look at the waste situation holistically and then applies it directly to the wallboard waste situation. In terms of product specific subcategory, the discussion centers on product specific tactics that improve wallboard use and management. Although many of the waste minimization strategies identified in the literature tend to be generic in nature, for the purposes of this research the strategies have been tailored towards the gypsum wallboard situation. The intention of these waste reduction measures is that they can be adapted to other construction materials where management has been a problem. Note that the discussion of each option was based solely on what was read in the literature and what was learned through the interviews.

At the end of each subsection (design, pre-construction, construction, and product specific) each recommended behavior, in that subsection, was rated using the sustainable IWM criteria set (see tables 8.3 to 8.6). Every option was compared individually to the current wallboard situation, which was based on what was learned in the previous section. Because the current wallboard rating only looked at wallboard generally and not throughout its life (creation, use, and disposal) a single rating in each criteria item was given. It should be noted that this rating was not based on the averages, but rather just a general rating based on what was learned throughout this research. Each recommended change in practice was rated based on the impact that behavioral change would have if implemented today. For instance, under the subsection: standard size materials, zeros (0) where given to every item in the criteria set because this behavior is currently being used by the construction industry. On the hand under the subsection deconstruction, there were both positive (+) and negative (-) ratings because this behavior for the most part is not being used by the construction industry today.

Although a majority of the behaviors in this section focus on waste minimization strategies, there are some that center on waste diversion. Although these options do not reduce wallboard waste totals, they do promote better disposal of wallboard material. The philosophy these options take is to divert wallboard away from landfills and instead deal with this material through reuse and recycling options. These behaviors are important in the overall management of wallboard waste and therefore are included under the change in practice section.

8.4.2 General Waste Minimization Strategies

8.4.2.1 Design Phase

Waste minimization strategies are a vital component in the design of any project. Often, the design phase of the project fails to recognize or implement these reduction initiatives because it is not seen as a design priority (Dainty and Brooke, 2004; Public Works and Government Services Canada, 2000). When architects, engineers, and contractors follow this latter philosophy, the waste minimization opportunities that exist become limited. Therefore, it is vital that waste reduction strategies are considered throughout the entire life of a project (Dainty and Brooke, 2004). When enough attention and thought is given to this during the design, construction, and deconstruction of a project, significant reductions in waste generation totals can be realized (Dainty and Brooke, 2004; Public Works and Government Services Canada, 2000)

8.4.2.1.1 Standard Size Materials

Designing projects that use standard sized materials is the first improvement that can be implemented. In instances where unconventional projects are built, unnecessary waste is produced (Dainty and Brooke, 2004). This waste is typically created because extra materials that have to be custom cut, are being used in order to fit the design (Dainty and Brooke, 2004; Recycling Council of Ontario, 2005; Verduga, 2004). When projects are designed to use standardized materials, a reduction in waste totals can be expected due to fewer material off-cuts (Ekanayake and Ofori, 2000; Johnston and Mincks, 1992; Recycling Council of Ontario, 2005; Verduga, 2004).

Many buildings are not designed to use standard size wallboard sheets. Instead, wallboard sheets have been created to fit a variety of buildings (see Appendices F and I). The variety of wallboard panels sold today, are made by wallboard manufacturers to accommodate a multitude of building designs (SRM Employee, 2009). In the case of residential projects, home design is based on pre-cut wood studs. While in commercial, industrial, and institutional structures, design is driven by masonry modules (16–inch (in.) blocks). Masonry influences the building design because of the difficulty in cutting this material. The fact that wallboard can be cut with a knife results in this material getting no consideration during building design (Gere, 2009; Greyhound Employee, 2009; Fryett, 2009).

8.4.2.1.2 Deconstruction

Designing projects that can be deconstructed at the end of a building's life is the second behavioral improvement considered (see section 4.6.1) (Leverenz, 2002; Public Works and Government Services Canada, 2000; Recycling Council of Ontario, 2005). If structures are designed for easy disassembly, it would greatly reduce the amount of waste produced at renovation and demolition projects (Public Works and Government Services Canada, 2000; Recycling Council of Ontario, 2005). When projects are designed and built with either reversible or tongue and grove connections, not only is the product disassembly easier to do, but there is a reduced risk of material damage. In instances where the only material fastening techniques are glue, nails, and screws, then material disassembly is more time consuming and more damaging to the material (Public Works and Government Services Canada, 2000).

Although wallboard disassembly is good in thought, in practice there are a lot of problems (see Appendices F and I). First, wallboard is a somewhat fragile material. For this material to stay intact, a lot of time and care would have to be spent on disassembly. If disassembly is done carelessly, dust/particle generations would become a problem. Second, the probability of these walls being clean and free from damage, is highly unlikely because most walls are abused and also contaminated with paint or decorative overlays. Third, the chance of the construction industry actually dissembling walls which are made of wallboard is doubtful due to the inexpensiveness of this material. Finally, there is a premium cost with buying demountable wallboard, and installing it is also more expensive (Gere, 2009; Greyhound Employee, 2009; Fryett, 2009). Therefore, the construction industry does not favour demountable walls because of the extra time and expenses associated with this type of wallboard (Greyhound Employee, 2009; Keating, 2009; Rosmar Employee, 2009). Although demountable wallboard does exit, it is only used in office buildings. Even here, the problem with this wallboard option is that the holes made for light switches and electrical outlets often eliminate the possibility of reuse (Greyhound Employee, 2009). Although the goal of demountable wallboard is to decrease wallboard waste totals, from discussions with individuals in the field, this is not the case. Demountable wallboard is unable to achieve this goal due to its breakability and wall contamination that occurs once these walls have been installed (Public Works and Government Services Canada, 2000).

8.4.2.1.3 Material Selection

Material selection is another important factor to consider. Selecting products that are known to be durable, repairable, and have a long lifespan could decrease construction waste totals since material replacement due to wear and tear will be reduced (Public Works and Government Services Canada, 2000; Leverenz, 2002). In terms of how material selection can positively reduce wallboard waste all depends on what type of wallboard is used (see sections 4.6.1 and 5.2.1). Because there are a number of wallboard products available, the more one is willing to spend on durability, the better the product will be (Gere, 2009; Fryett, 2009). When it comes to decisions regarding which wallboard product to use (see Appendices F, H, I), architects and contractors base their decision on building code regulations, cost, satisfaction of the client, aesthetic pleasure, ease of installation, and does it fit the architectural features of the structure (Gere, 2009; Fryett, 2009; Keating, 2009; Rosmar Employee, 2009). Although these considerations are important, this industry needs to be more willing to recommend higher quality wallboard panels, no matter what the project type. The use of higher quality panels will result in a reduction in wallboard replacement due to material deterioration (Binggeli, 2008; National Gypsum, 2008).

Table 8.3 Evaluation of design phase changes using the sustainable IWM criteria

Change in Practices Category					
Evaluation Tools (Criteria)	**Design Phase Changes**				
	Current Wallboard Situation (Base Case Scenario)	**If Recommended Behavior was Implemented**			
		Standard Size Materials (SSM)	Deconstruction (D)	Material Selection (MS)	Justification for Rating
Environmental Impacts with Current Behavior • *Land* • *Water* • *Air* • *Habitat disturbance and modification* • *Species disturbance and biodiversity loss*	 --- --- --- -- --	 0 0 0 0 0	 ++ ++ ++ ++ ++	 ++ ++ -- ++ ++	**SSM** = wallboard manufacturers accommodate this industry by offering a variety of products (this option is being used by the industry). **D** = if wallboard was dissembled for reuse less wallboard will need to be manufactured and therefore, less ecological impacts. **MS** = higher quality material leads to less wear and tear however, chemical additives need to be injected into the panel, which adversely impacts air quality.
Health Impacts	---	0	--	--	**SSM** = option is already being used by industry and therefore, no added health impacts. **D** = an addition health problem is the release of dust/particle with wallboard disassembly. **MS** = synthetic chemicals are added to the panels to increase durability and function leading to adverse health impacts.
Energy Consumption	---	0	++	++	**SSM =** option is already being used by the industry and therefore, same consumption levels will be experienced. **D** = reusing panels means less manufacturing of new products. **MS** = less wear and tear equals longer lifespan and

					decrease need for new panels.
Resource Availability	+++	0	++	++	**SSM =** option is already being used therefore gypsum mineral consumption will be the same. **D** = reusing panels means less manufacturing of new products. **MS** = less wear and tear equals longer lifespan and decrease need for new panels.
Travel Distance (rating based on use and disposal)	++	0	+	+	Less wallboard being purchased and discarded will lead to less travel distance.
Product Functionality • *Durability* • *Aesthetic Appeal* • *Maintenance ease* • *Installation ease*	 - +++ +++ +++	 0 0 0 0	 - - - --	 +++ 0 0 0	**SSM =** will not have an influence because wallboard is not physically being changed. **D** = with wallboard being reused there is a higher chance of damage, which impacts the panels functionality. **MS** = selecting products that are stronger and more resistant to the elements leads to higher durability.
Product Rating • *Insulation* • *Noise Resistant* • *Fire Resistant* • *Mold Resistant* • *Moisture Resistant*	 + - - -- --	 0 0 0 0 0	 0 0 0 0 0	 +++ +++ +++ +++ +++	**SSM + D =** will not have an effect because wallboard is not physically being changed. **MS** = the more one spends on paneling the higher the product rating will be.
Product Availability	+++	0	0	0	Will have no impact on product purchasing since wallboard will continue to be sold in the same locations.
Affordability	+++	0	--	---	**SSM =** same wallboard being used today equals same price. **D** = more expensive since product disassembly is a premium feature. **MS** = more expensive since additional materials are added to increase durability and rating.
Stakeholder Attitude	+++	0	---	---	**SSM =** already a high familiarity with the product. **D** = installation technique is more difficult and therefore, takes longer to install. **MS** –increased features are not seen as contributing substantially more than a tradition panel (increase cost).

Stakeholder Participation	---	0	0	0	All three behaviors have no impact on communication.
Education	---	0	--	0	**SSM + MS** = installation techniques will be the same. **D** = installation is not only different, but also more difficult.
Employment	+++	0	-	-	**SSM** = same wallboard being used today equals same level of employment. **D** = reusing panels means less manufacturing of new products and therefore, the employment of less individuals. **MS** = less employees are needed because the lifespan of the product is higher and chances of wear and tears is reduced.
System Vulnerability	++	0	+	+	**SSM =** same wallboard being used today equals same product functionality level. **D** = extends the life of wallboard through disassembly and reuse. **MS** = extends the life of wallboard by adding additives to increase product rating and functionality.
Product Uncertainty	+++	0	0	---	**SSM + D =** no adding of additional chemicals to the product. **SM** = addition of synthetic chemicals to the product.
Regulations	++	-	+++	+++	**SSM =** no regulations regarding use of standard size materials. **D** = Ontario Ministry of Municipal Affairs and Housing Regulation 403/97 Section 2 – regulates the use of reusing materials. **MS** = panels must be a certain rating if they are used as an interior wall. It is regulated by the OBC.
Enforcement	---	N/A	+++	+++	**SSM =** with no regulation in place there can be no enforcement. **D + MS** = both regulations are enforced.
Product Donation	+	0	N/A	0	**SSM + MS** = will have no impact on donation. **D** = these panels will not be donated since they will be reused.
Donation Restrictions	--	0	N/A	0	**SSM + MS** = will have no impact on donation restrictions.

					D = these panels will not be donated since they will be reused.
Service Availability	++	0	0	0	These three behaviors do not impact the adding of additional services.
Material Breakdown	---	0	0	-	**SSM + D** = no impact on material breakdown. **MS** = the addition of extra materials to the panel will hinder its ability to breakdown.
End Life of Product Management • *Reduce* • *Reuse* • *Recycle*	--- -- ---	0 0 0	0 ++ 0	0 0 0	**SSM + MS** = these behavior are not encouraging the employment of the waste minimization hierarchy. **D** = the promotion of product disassembly will lead to an increase in panel reuse.
Future Consideration	--	0	++	--	**SSM =** same wallboard being used today equals same impact on future generations. **D** = reuse of materials means decreases in manufacturing levels and landfill disposal totals, which will positively impact the future. **MS** = the adding of chemicals will reduce air quality, which will lead to negative impacts.
Holistic Understanding	-	0	+	+	**SSM** = will not provide any additional insight regarding wallboard functioning. **D** = by reusing wallboard panels unnecessary waste creation will be reduced, which will have a positive impact. **MS** = with reduce wear and tear, the lifespan of wallboard will increase, which will positively influence the system.

Key: --- = extremely negative --= negative - = somewhat negative
0 = neutral + = somewhat positive ++ = positive +++ = extremely positive
N/A = Not Applicable INA = Information not Available

8.4.2.1.4 Concluding Remarks and Recommendations for Design Phase Changes

The ratings (see table 8.3) given to the three behaviors recommended under the design phase category, illustrates some interesting findings. With the first recommendation, standard size materials, the table indicates that this behavior has already been adopted by the construction industry. In the case of deconstruction, the ratings demonstrate that this behavior has not been adopted. But from the rating it would appear that if demountable wallboard was used more, it would not play a role in reducing wallboard waste. From a review of the literature and through discussions with interviewees, it is clear that wallboard installers lack the proper knowledge when it comes to the assembly of this wallboard. Furthermore, hole creation and surface contamination are additional reasons why demountable wallboard would not lead to reduction in wallboard waste creation totals. Even though demountable wallboard could lead to positive environmental impacts, energy consumption, and resource availability, there are also a number of drawbacks with this paneling, which include installation ease, affordability, need for added education, and stakeholder attitude. Because of these drawbacks, it is no wonder why further advancements in the design of demountable wallboard is needed if an improvement in wallboard waste reduction totals is ever going to be experienced. In terms of material selection, once again there is a combination of positive and negative impacts. By selecting materials that have higher durability, increased cost will occur. From what was learned through the interviews, cost and abiding by building code regulations are the two key factors that influence decision making. By selecting panels that have a higher durability, an increase panel life should result since a stronger and more resistant wallboard will be installed.

Once again as with any group of options, there are going to be trade-offs. In the case of deconstruction, increased cost and installation time will result in panels that can be dissembled and reused again. With material selection, buying higher end panels will reduce the chances of these panels becoming damaged due to deterioration or an inability to protect itself from the outside elements. Highlighted in the chart are a number of recommendations given to improve the design phase of a project.

- Architects/designers should select wallboard sheet sizes closest to the wall height being constructed to reduce wallboard off-cut totals.
- Construction industry should encourage custom design practices that focus on minimizing material waste.
- Improvements in demountable wallboard should be made (to increase strength, remove decorative overlays, and permit easier assembly and disassembly) before these panels are promoted more within the construction industry.
- Education should be available to wallboard hangers regarding the assembly and disassembly of demountable wallboard.
- Architects and builders should select wallboard panels that are more durable, in order to eliminate some of the damage (holes and inability to handle exposure to the elements) that arise with cheaper wallboard products

8.4.2.2 Pre-construction Phase

Pre-construction is another phase where waste generation totals can be reduced. The importance of planning and having a solid understanding of the project can lessen the overall creation of unnecessary waste (Recycling Council of Ontario, 2005). Common strategies employed during the pre-construction phase include careful planning, up-to-date inventory, accurate ordering, correct and complete design, and finally enforcement of contractual clauses that penalize poor waste practices (Dainty and Brooke, 2004; Recycling Council of Ontario, 2005; Verduga, 2004).

8.4.2.2.1 Planning

All too often not enough time or attention is dedicated towards developing an installation plan. With no preparation in place comes excess material waste. When careful planning is done, better material purchasing occurs because material with the correct size is ordered and excess material purchasing is eliminated. Careful planning leads to less waste due to a decrease in the amount of material remaining after a project's completion (Gere, 2009; Recycling Council of Ontario, 2005).

In the case of wallboard, if hanging diagrams are used, there would be a reduction in wallboard waste totals. Wallboard hangers not only would have a better sense of how many wallboard sheets are needed to complete the project, but also a greater understanding of how these sheets fit together. This solid understanding would help hangers reduce excess material and this in turn would reduce the amount of wallboard sheets remaining after a project's completion (Gere, 2009). Discussion with a wallboard recycler indicated that a majority of wallboard waste entering his facility is a combination of either clean full size sheets or large off-cut pieces. What this illustrates is that poor planning leads to poor installation, which in turn leads to excess wallboard waste creation (New West Gypsum Employee, 2009; Sittler Employee, 2009). Although wallboard hangers like to think they take part in good pre-preparation steps (see Appendix H), a review of the literature (Recycling Council of Ontario, 2005) and several discussions with waste processors and general contractors (see Appendices G and I) indicated that poor pre-planning leads to significant wallboard waste generation totals.

8.4.2.2.2 Up-to-date Inventory

An up-to-date inventory is another type of waste reduction practice. When construction companies have an accurate inventory list, the ordering of unnecessary materials is eliminated. Excess product ordering occurs due to a lack of material awareness when there are no inventory records or they are not up-to-date (Dainty and Brooke, 2004; Ekanayake and Ofori, 2000). The purchasing of unneeded materials can lead to increase waste totals because any material remaining might not be saved by the construction company. Reasons for companies' unwillingness to save on excess wallboard material include cheap price, ease of purchase, high probability of damage during transport, highly breakable, and too cumbersome to move (Gere, 2009). If site managers had up-to-date records regarding the delivery of products on-site and the amount of product delivered, ordering mistakes would be reduced (Dainty and Brooke, 2004).

Knowing exactly how many wallboard sheets are on-site will eliminate unnecessary ordering. General contractors (see Appendix I) that have been interviewed, revealed that their companies do not have up-to-date product inventory records. Records are not used because they only order what they need. Any wallboard surplus remaining is discarded if their next project site is too far away or the wallboard sheets are not full size (Greyhound Employee, 2009; Keating, 2009). Inventory records are typically used by large construction firms and trade workers. These companies have material records because of the large number of projects they work on and they can always use more materials. Also ordering more material will reduce their per unit price (Greyhound Employee, 2009). The wallboard hanger interviewed (see Appendix H) did validate what was said by the general contractors. An up-to-date inventory list is used to monitor the amount of wallboard materials in their company's warehouse (Rosmar Employee, 2009).

8.4.2.2.3 Accurate Ordering

Accuracy in ordering and elimination of ordering errors is another waste minimization strategy that could be adopted (Dainty and Brooke, 2004; Johnston and Mincks, 1992). Although this tactic sounds similar to the previous category, it is different. Instead of determining inventory availability, this strategy prides itself in ordering enough correct material to complete a job while having the least amount of excess material. For this recommendation to work, it is again essential to have an up-to-date inventory list (Dainty and Brooke, 2004; Recycling Council of Ontario, 2005; Verduga, 2004). Knowledge about existing material will help to make the remaining order more precise. Again, an order that is more accurate reduces wallboard waste totals by decreasing the amount of wallboard material remaining after a project's completion. A mixed response was received with regards to the construction industry and whether ordering errors exist (see Appendices H and I). The Rosmar Employee indicated "yes" while the general contractors stated "no" (Greyhound Employee, 2009; Keating, 2009; Rosmar Employee, 2009). The fact that material leftover occurs after the completion of a project indicates these general contractors are using flawed ordering techniques. Furthermore, discussion with a wallboard processor indicated that full sheets are often times brought to their recycling facility. If material ordering is done correctly, clean full sheets should not be entering this facility (Greyhound Employee, 2009; Keating, 2009; NWG Employee, 2009). From what was read in the literature and verified with the wallboard hanger, although inaccurate ordering and ordering errors do exist, the problem is not serious (Recycling Council of Ontario, 2005; Rosmar Employee, 2009).

8.4.2.2.4 Correct Design

Ensuring correct design before construction begins is another step that could positively contribute to a reduction in wallboard waste generation totals. In many instances, the design specifications given at the beginning of a project are not the same design requirements at its completion. When contractors and construction workers are unaware of design changes, excess waste is produced. This waste is created when newly constructed areas have to be torn down because they no longer meet the new design specification (Recycling Council of Ontario, 2005).

It is important to know, which individuals in the construction industry have the authority to make design changes. Also, do these individuals typically work on or off-site (see Appendix F)? Project type influences who in the industry can make design changes. In Ontario, when design changes are made to a single family home, the builder/general contractor has the power to approve these changes as long as they are registered under Tarion (a warranting insurance company). In the case of industrial, commercial, and institutional projects, all changes must be approved by a registered architect. These results indicate that there is better communication on residential projects since design changes can be made by the builder, who is typically on-site. With industrial, commercial and institutional projects, design changes must be approved by an architect, who typically works off-site. In the latter case, communicating any changes may take longer and therefore areas may be constructed incorrectly (Fryett, 2009; SEM Employee, 2009).

Discussions with a general contractor and a trade worker were able to validate these claims. Mr. Keating whose firm only works on the construction of residential projects, indicated that wallboard waste is never created due to changes in the design. He explained that residential builders have the power to make design changes and when changes are made, everyone is told (Keating, 2009). In the case of the wallboard hanger, he indicated that every project he has worked on (commercial, industrial, and institutional), excess wallboard waste was created. This waste was generated due to changes made in the design in which insufficient notice was given (Rosmar Employee, 2009).

8.4.2.2.5 Development and Enforcement of Contractual Clauses

A further step this industry could take to help eliminate bad waste practices is the development and enforcement of contractual clauses that penalize poor waste behaviors. The goal of this waste prevention method is to make trade workers more accountable for their waste behaviors. These penalties can range from minor to severe and from a monetary fine to an actual job firing (Dainty and Brooke, 2004). Evaluating trade workers' installation techniques and waste management practices helps to highlight where problems exist and where changes need to be made. Having a clause in sub-contractors' contracts that holds them accountable for their actions will help them eradicate any bad behaviors they may use (Dainty and Brooke, 2004).

If wallboard hangers knew that they would be penalized for employing poor installation techniques, a dramatic decrease in wallboard waste totals could be realized. Both general contractors agreed that having a clause in trade workers' contracts in principle is a good idea. The only problem is enforcing it. Because this industry tends to work behind schedule, it would be difficult to dedicate the time and personnel to monitor sub trades behaviors (Greyhound Employee, 2009; Keating, 2009). If wallboard hangers have a contract clause that penalizes them for making too many off-cuts or not using their off-cut pieces, many problems could arise. Forcing wallboard hangers to reduce their waste by using their off-cut pieces will result in more time needed to build the walls. By adding extra wall installation time, workers will not only get further behind, which will reduce their pay (which is based on how much they install), but they may become frustrated and quit. Right now the construction industry is in a no win situation, if wallboard hangers try to use their off-cuts to produce less waste, not only will it take more time but the final wall product will be lower quality (Keating, 2009).

Table 8.4 Evaluation of pre-construction phase changes using the sustainable IWM criteria

Change in Practices Category							
	Pre-Construction Phase Changes						
		If Recommended Behaviors was Implemented					
Evaluation Tools (Criteria)	**Current Wallboard Situation (Base Case Scenario)**	Planning (P)	Up-to-date Inventory (UI)*	Accurate Ordering (AO)	Correct Design (CD)	Development and Enforcement of Contractual Clauses (DECC)	Justification for Rating
Environmental Impacts with Current Behavior • *Land* • *Water* • *Air* • *Habitat disturbance and modification* • *Species disturbance and biodiversity loss*	 --- --- --- -- --	 ++ ++ ++ ++ ++	 + + + + +	 ++ ++ ++ ++ ++	 + + + + +	 ++ ++ ++ ++ ++	**P** = better planning will lead to better use of the product, which will decrease the amount of wallboard needed for a project (reduces manufacturing levels) and its disposal total. **UI** = up-to-date inventory will lead to less waste because companies will use the material they already have instead of ordering new materials. Furthermore, this behavior will reduce wallboard manufacturing totals. **AO** = ordering only enough material to complete the project will eliminate any excess wallboard sheets, which will lead to less wallboard waste. Furthermore, with more accurate ordering, less wallboard will be needed, which will reduce wallboard manufacturing totals. **CD** = when workers are aware of design changes, the need to tear down a newly constructed wall because of a design change will be reduce. This action will decrease wasteful use of wallboard (reduces manufacturing levels) and lessen its disposal.

							DECC = If wallboard hangers were held accountable for wasteful behaviors it will result in more effective wallboard hanging, which will lead to less waste generation totals and less wallboard manufacturing.
Health Impacts	---	++	+	++	+	++	Health problems will be less because manufacturing and disposal totals will be lower.
Energy Consumption	---	++	+	++	+	++	Energy consumption will be less because manufacturing totals will be lower.
Resource Availability	+++	++	+	++	+	++	A lower amount of gypsum minerals will be needed because manufacturing totals will be reduced.
Travel Distance (rating based on use and disposal)	++	+	+	+	+	0	**P + UI + AO + CD =** with better planning, ordering, and design it will lead to less wallboard being purchased and discarded, which will lead to less travel distance. **DECC =** Will not impact travel distance since wallboard will be sold and disposed of in the same locations.
Product Functionality • *Durability* • *Aesthetic Appeal* • *Maintenance ease* • *Installation ease*	 - +++ +++ +++	 0 0 0 0	 0 0 0 0	 0 0 0 0	 0 0 0 0	 -- --- 0 --	**P + UI + AO + CD =** will not have an influence because wallboard is not physically being changed. **DECC** = if wallboard off-cuts are used: durability will be reduce, wall appearance will not be as smooth, and installation will be more difficult and time consuming.
Product Rating • *Insulation* • *Noise Resistant* • *Fire Resistant* • *Mold Resistant* • *Moisture Resistant*	 + - - -- --	 0 0 0 0 0	 0 0 0 0 0	 0 0 0 0 0	 0 0 0 0 0	 0 0 0 0 0	Will not have an influence because wallboard is not physically being changed.
Product Availability	+++	0	0	0	0	0	Will have no impact on product purchasing since wallboard will continue to be sold in the same locations.
Affordability	+++	0	0	0	0	0	Same wallboard being used today equals same price.
Stakeholder Attitude	+++	--	-/0	-	-/0	---	**P** = industry believes there preparation is good, information indicates otherwise. **UI =** some in the construction industry use up-to-date inventory lists, while others do not and feel that it is not necessary. **AO** = mixed agreement regarding ordering techniques and their accuracy. Although many in the industry feel they are doing a

							good job, it seems that more of the construction industry is not taking part in proper ordering behaviors. **CD** = mixed agreement within the construction industry regarding crew members knowledge about design changes. In the commercial, industrial, and institutional sector insufficient notices is given to wallboard hangers when design changes are made (off-site). In the residential sector communication is immediate because builders (who work on-site) have the power to make changes and tell everyone immediately. **DECC** = wallboard hangers will reject implementation of this behavior because it is detrimental to their wellbeing. The fact that financial penalties will be used as a disincentive for poor practices will deter wallboard hangers to agree to a contractual clause.
Stakeholder Participation	---	++	+	++	++	--	**P =** if better planning is needed, greater discussion will take place within the industry. **UI** = with an inventory list, it communicates to the workers what products are in the company warehouse. **AO** = open communication needs to take place to help this industry adopt better ordering strategies. **CD** = better communication between the foremen and work crew when it comes to design changes. **DECC** = willingness by wallboard hangers to agree to a contractual clause will be nonexistent.
Education	---	--	-/+	-/+	-/+	+	**P** = industry is not knowledgeable about pre-planning practices. **UI** = companies that already employ an inventory list are well educated on how to use it, while companies who do not have an inventory list have low knowledge of this behavior. **AB** = certain stakeholder's are knowledgeable about proper ordering techniques while others have very limited knowledge. **CD** = residential sector is more knowledgeable about communicating design changes to their workers compared to the commercial, industrial, and institutional sectors. **DECC** – most wallboard hangers have the knowledge about proper wallboard installation techniques, the problems is that these techniques may take extra time and therefore, wallboard hangers are not willing to use them.

Employment	+++	--	-	--	-	---	**P** = the need for less panels means reduce manufacturing of new products and therefore, employment of less individuals. **UI** = less panels are needed because existing stock is being used. This means ordering of new products will be reduced leading to less manufacturing of new products whereby reducing employment. **AO** = less panels because proper ordering will be done, which will in turn reduce manufacturing levels of new products and therefore lead to the employment of less individuals. **CD** = with sufficient notice given to crews about design changes, this behavior will decrease wasteful use of wallboard and in turn lessen the need for the product -less manufacturing means fewer employees. **DECC** = two sectors could be influenced. Wallboard hangers who show inappropriate installation techniques (could be fired from the job) and wallboard manufacturers (decrease wallboard use comes less manufacturing, which negative impacts employment).
System Vulnerability	++	++	+	++	+	++	**P** = effective installation techniques will lead to less waste. **UI** = product inventory will lead to less ordering, which causes a reduction in waste. **AO** = effective ordering and elimination of ordering errors will lead to less waste, which will improve the functioning of the system. **CD** = behavior will reduce the need to demolition an area due to changes made in the design, which will in turn improve the system's functioning. **DECC** = with better installation techniques comes a reduction in waste totals, which will improve the functioning of the system.
Product Uncertainty	+++	0	0	0	0	0	No adding of additional chemicals to the product.
Regulations	++	-	-	-	-	-	No regulation in place.
Enforcement	---	N/A	N/A	N/A	N/A	N/A	With no regulation in place there can be no enforcement.
Product Donation	+	0	0	0	0	0	Will have no impact on donation.
Donation Restrictions	--	0	0	0	0	0	Will have no impact on donation restrictions.

Service Availability	++	0	0	0	0	0	These behaviors do not impact the adding of additional services.
Material Breakdown	---	0	0	0	0	0	No impact on material breakdown.
End Life of Product Management • *Reduce* • *Reuse* • *Recycle*	 --- -- ---	 +++ 0 0	 + 0 0	 ++ 0 0	 + 0 0	 ++ ++ 0	**P** = effective installation will play a role in reducing wallboard generation totals, but will have no impact on reuse or recycling. **UI** = by using existing wallboard materials instead of continuously purchasing new product, it will lead to a reduction in wallboard consumption. **AO** = with more accurate orders and fewer errors it will lead to a reduction in wallboard waste generation totals, but will have no impact on reuse or recycling. **CD** = informing workers about design changes will reduce the need to demolition newly constructed areas, which will reduce unnecessary wallboard waste. **DECC** = by forcing wallboard hangers to be more accountable not only will it encourage them to be less wasteful with their materials, but it will also promote them to reuse their wallboard scrap.
Future Consideration	--	++	+	++	+	++	**P + AO + CD** = reduction in material use means decreases in manufacturing levels and landfill disposal totals, which will positively impact the future. **UI** = by using existing wallboard material instead of continuously purchasing new product, it will lead to a reduction in wallboard consumption, which will have a positive impact on the future. **DECC** = reduce and reuse of materials means a decreases in manufacturing levels and landfill disposal totals, which will positively impact the future.
Holistic Understanding	-	++	+	++	+	++	**P** = with better understanding of effective paneling configurations it will lead to a better installation techniques, which will positively impact the system. **UI** = by having an inventory list unnecessary ordering will be eliminate, which will positively impact the system. **AO** = with more accurate ordering and fewer errors will come less waste, which will positively impact the functioning of the system. **CD** = with better communication of design changes will come

							less need to demolition an area, which will reduce waste totals and lead to positive system functioning. **DECC** = through penalties better installation techniques will be taught and adopted, which will lead to a positive system functioning.

* Up-to-date inventory ratings are based on construction companies that do not keep inventory lists (residential construction companies and small-scale institutional, commercial, and industrial construction companies)

Key: --- = extremely negative --= negative - = somewhat negative

0 = neutral + = somewhat positive ++ = positive +++ = extremely positive

N/A = Not Applicable INA = Information not Available

8.4.2.2.6 Concluding Remarks and Recommendations for Pre-Construction Phase Changes

The ratings in table 8.4 indicate that many of the recommended behaviors have the same rating type, either positive, zero, or negative, in each criteria item. The only difference between these recommendations and their ratings is their degree of impact (two positive compared to one positive). What these results illustrate is different levels of implementation between the recommended behaviors. Planning, accurate ordering, and the development and enforcement of contractual clauses, are all behaviors that are either not used or infrequently used by the industry. Up-to-date inventory and correct design are waste reduction behaviors, which are being utilized, but could be implemented even more. Because the current level of implementation for each recommended behavior is slightly different, larger differences in positive and negative impacts will be experienced for recommended behaviors that are not being used compared to behaviors that are somewhat being used. For all five behaviors, all options need to be utilized, but with varying degrees of implementation. If any or all of these behaviors are employed to their fullest, it would improve the overall management of wallboard in a positive way. However, the trade-off with utilizing these behaviors is the extra time it would take to properly follow and monitor them. Therefore, the following recommendations focus on behaviors that need to be implemented under the pre-construction phase to improve wallboard waste generation totals.

- Wall installation plans should be prepared prior to an order being made to improve order accuracy and eliminate order errors.
- Wallboard hangers should always use a wallboard installation plan. This action will improve the efficiency of wallboard hanging, which in turn will reduce wallboard waste.
- Inventory records should be used by all construction and sub trade companies.
- Inventory records should be kept up-to-date and they should be reviewed before a material is ordered.
- Better communication should be implemented, especially on commercial, industrial, and institutional projects, to inform workers about design changes. The communication can include daily announcements informing all crew

members whether design changes have been made, supplying contractor/sub trades with up-to-date designs of the project. Also, better communication between the client, architect, and contractor regarding design changes is needed.

- Enough notice should be given to sub trades (electricians, framers, plumbers, etc…) to deal with any changes made to the design of a project.
- Contractual clauses should be used to strengthen the motivations of wallboard hangers to be accountable for their waste practices and poor disposal techniques.
- Incentives for use of proper installation techniques (reduce waste means less tipping fee) should be used for projects, in which the general contractor is responsible for the disposal of waste.
- General contractors should encourage wallboard hangers to use their off-cut pieces (half original panels size or larger).

8.4.2.3 Construction Phase

Several waste prevention strategies are available and can be used during the construction phase of a project. These methods include better site control and communication by the general contractor, improved transportation techniques and better on-site storage to prevent material damage, use of source separation programs, and increased landfill tipping fees for materials that can be reused and recycled (Ekanayake and Ofori, 2000; Recycling Council of Ontario, 2005; Yahya and Boussabaine, 2006).

8.4.2.3.1 Better Site Control

Managing a construction site so everything runs smoothly is an extremely difficult task to do due to the unforeseeable circumstances that can arise and derail a project from its timely completion. The importance of good site control and effective communication between the contractor and sub trades plays a significant role in the amount of waste produced (Ekanayake and Ofori, 2000; Recycling Council of Ontario, 2005). When communication breaks down between the foremen and the crew, problems typically arise (use of a wrong material and/or design problem). Better site control brings earlier awareness of such problems. Identification and communication of problems not only assists in the implementation of solutions, but also stops these problems from getting out of hand (Recycling Council of Ontario, 2005).

All waste processors (see Appendix G) believe that better site control by the general contractor will decrease wallboard waste totals (Arsenault, 2009; New West Gypsum Employee, 2009; Sittler Employee, 2009; Waring, 2009). These individuals also feel that the construction industry is still partaking in poor waste behavior as indicated by the amounts and types of waste entering their facilities (Arsenault, 2009; New West Gypsum Employee, 2009). Having project sites better managed reduces the operating costs since the job will be done correctly the first time. When jobs are done properly, there is no need for extra time and/or resources (Sittler Employee, 2009). Furthermore, when sites are controlled better, there is less chance of material damage. Having designated locations on-site where materials can be stored and be out of danger from traffic flows and weather elements are further characteristics of a properly run site. If a general contractor has better communication with their wallboard hanger, the generation of wallboard waste due to design changes, poor practices, ordering errors and material damage will be reduced. Better site control through better communication will play a role in decreasing wallboard waste totals.

8.4.2.3.2 Poor Transportation and On-site Storage

Inappropriate transportation procedures and inadequate on-site material storage areas are other factors that help to increase construction waste totals. Because brand new materials can be damaged by the adoption of poor practices, changes in material delivery and on-site storage are two tactics that can lead to major reductions in waste generation totals (Ekanayake and Ofori, 2000; Verduga, 2004).

Discussion with contractors and a sub trade worker (see Appendices H and I) indicated that some wallboard waste is created from poor transportation and on-site storage practices. However, all three stressed that the amount of waste created from these practices is minor compared to other behaviors. In instances where a substantial number of wallboard sheets are damaged due to poor transportation methods, new wallboard is sent by the manufacturer. The damaged wallboard then becomes the responsibility of the manufacturer. Because wallboard sheets are delivered to the site as close to installation day as possible and are covered when on-site, few wallboard sheets are ruined (Greyhound Employee, 2009; Keating, 2009; Rosmar Employee, 2009). Although contractors feel that transportation and poor on-site practices do not significantly contribute to wallboard waste creation totals, waste is still being produced from these behaviors. If wallboard suppliers and the construction industry were to improve upon delivery practices and on-site storage even more, it would lead to an even smaller amount of new wallboard waste being discarded.

8.4.2.3.3 Source Separation

Introducing source separation programs represents yet another approach to improve wallboard management. The goal of this option is to divert waste away from landfills by employing better waste collection techniques (Theisen, 2002; Smith-Pursley, 1997; Yahya and Boussabaine, 2006). As previously discussed in Chapter 4 under the sub-section 4.6.3 *Source Separation*, there are four main source separation programs available. Having a thorough knowledge about what source separation program to implement can lead to enormous reduction in waste generation totals. In selecting a source separation program two important factors need to be considered 1) what is the project and 2) what are the local conditions (Smith-Pursley, 1997). The benefit of knowing what the project is helps to differentiate between source separation programs that will work versus programs that will not (Dainty and Brooke, 2004; Smith-Pursley, 1997).

Construction waste is managed differently in operations described by the interviewees (see Appendices F, H, and I), Mr. Keating revealed that his company does handle the disposal of construction waste, but does not source separate the waste. All waste produced on-site is discarded in the landfill (Keating, 2009). The Greyhound employee indicated that there is a degree of sorting at their sites, but that most waste is handled by each sub-contractor. When his company is responsible for the waste, the only materials sorted are cardboard and metals. All other materials are discarded in a mixed bin that is sent to the landfill for final disposal (Greyhound Employee, 2009). The sub-contractor said his wallboard waste is always separated from other construction waste. Material separation is done because this is the only material he deals with and most project sites he works on are LEED certified (Rosmar Employee, 2009).

Better management of construction waste was the common theme stated by the waste processors (Sittler Employee, 2009; Waring, 2009). A significant reduction in the amount of wallboard waste discarded in landfills could be experienced if source separation programs were better implemented. The interviewees (see Appendix G) believed that the best source separation program to be employed in Ontario, is to have designated wallboard bins located at transfer stations and at landfill sites. If wallboard depots were established in more of these disposal areas, greater amounts of wallboard would be diverted away from landfills. Transfer stations and landfill sites that have implemented this off-site source separation program have been successful in increasing the amount of wallboard waste sent for recycling (New West Gypsum Employee, 2009; Sittler Employee, 2009). The problem with launching a wallboard diversion program is the risk of the wallboard waste being contaminated with other construction waste. This added contamination could cause recycling facilities to increase their disposal fees because of the extra time and manpower needed to separate the materials. Because these bins would be managed at landfills and transfer stations, added disposal fees would be enforced at these disposal facilities, which would make this option less appealing (Arsenault, 2009).

8.4.2.3.4 Landfill Tipping Fees

Increasing landfill tipping fees is yet another waste reduction strategy to consider. If the construction industry were forced to pay higher landfill tipping fees, waste prevention strategies would be implemented to counteract these higher disposal fees (McCamley, 2004). Because landfill disposal fees are relatively inexpensive, this industry has failed to put the necessary time or effort into adopting better waste reduction strategies. This industry has been satisfied with doing little to improve their waste generation totals (Recycling Council of Ontario, 2005; Smith-Pursley, 1997). If landfill tipping fees were increased, greater resources would be dedicated to identifying alternative disposal practices. Because nothing is stopping the construction industry from continuing environmentally irresponsible disposal practices, wallboard waste in Southern Ontario is still being landfilled (Arsenault, 2009). The only way this industry will move away from landfill disposal and move towards wallboard recycling, is if there is greater disparity in tipping fees (see Appendix G). Currently, facilities that recycle wallboard waste have tipping fees that are at or just below local landfill tipping fees. If there was a greater price difference between the two, it would force this industry to either start recycling their wallboard waste or implement better waste reduction initiatives to lessen the amount being discarded (Gere, 2009; Waring, 2009). The Greyhound Employee (2009) indicated that landfill tipping fees would have to double before this industry will start to change its practices.

Table 8.5 Evaluation of construction phase changes using the sustainable IWM criteria

Change in Practices Category						
	Construction Phase Changes					
		If Recommended Behaviors was Implemented				
Evaluation Tools (Criteria)	**Current Wallboard Situation (Base Case Scenario)**	Better Site Control (BSC)	Poor Transportation and On-site Storage (PTOS)	Source Separation (SS)	Landfill Tipping Fees (LTF)	Justification for Rating
Environmental Impacts with Current Behavior						**BSC =** better site control will lead to better use of the product, which will decrease the amount of wallboard needed for a project (reduces manufacturing levels) and its disposal total. **PTOS** = better handling of new wallboard will lead to less damage, which will decrease the need to purchase new wallboard and discard damaged new pieces. **SS** = if some sort of source separation program(s) was implemented for wallboard waste, significant diversion rates will be experience. Instead of landfilling this waste it will either be sent for donation or recycling, which will reduce the ecological impacts association with landfilling. **LTF** = this option encourage the implementation of both waste prevention measures as well as waste
• *Land*	---	+++	+	++	+++	
• *Water*	---	+++	+	++	+++	
• *Air*	---	+++	+	++	+++	
• *Habitat disturbance and modification*	--	+++	+	++	+++	
• *Species disturbance and biodiversity loss*	--	+++	+	++	+++	

						diversion techniques. If these two approaches were used it will lead to decreases in wallboard use and landfill disposal.
Health Impacts	---	+++	+	-/++	-/+++	**BSC + PTOS** = health problems will be less because manufacturing and disposal totals will be lower. **SS** = health problems will be less because waste will be diverted away from landfills. However recycling will lead to increase dust/particle generation, which adversely impacts human respiratory system, eyes, skin, and nose. **LTF** = health problems will be less because manufacturing totals will be lower and any generated waste will be diverted away from landfills. However recycling will lead to increase dust/particle generation, which adversely impacts human respiratory system, eyes, skin, and nose.
Energy Consumption	---	+++	+	0	++	**BSC + PTOS + LTF=** energy consumption will be less because manufacturing totals will be lower. **SS** = energy consumptions will not change since manufacturing totals will not be influenced.
Resource Availability	+++	+++	+	+++	+++	**BSC + PTOS =** a lower amount of gypsum minerals will be needed because manufacturing totals will be reduced. **SS** = recovered gypsum minerals (through recycling) can be reused in new wallboard manufacturing. **LTF** = a lower amount of gypsum minerals will be needed because manufacturing totals will be reduced. Furthermore, recycling these panels will allow the recovered gypsum minerals to be used in new wallboard manufacturing.
Travel Distance (rating based on use and disposal)	++	+	+	--	-	**BSC + PTOS** = it will lead to less wallboard being damaged and therefore less need to purchase new wallboard sheets, which will lead to less travel distance **SS** = fewer wallboard recyclers in the province

						result in greater distances being traveled to unload this waste. **LTF** = If this waste is landfilled there are numerous facilities in the area. If this waste is recycled fewer facilities exist resulting in further distance having to be traveled.
Product Functionality • *Durability* • *Aesthetic Appeal* • *Maintenance ease* • *Installation ease*	 - +++ +++ +++	 0 0 0 0	 0 0 0 0	 0 0 0 0	 0 0 0 0	Will not have an influence because wallboard is not physically being changed.
Product Rating • *Insulation* • *Noise Resistant* • *Fire Resistant* • *Mold Resistant* • *Moisture Resistant*	 + - - -- --	 0 0 0 0 0	 0 0 0 0 0	 0 0 0 0 0	 0 0 0 0 0	Will not have an influence because wallboard is not physically being changed.
Product Availability	+++	0	0	0	0	Will have no impact on product purchasing since wallboard will continue to be sold in the same locations.
Affordability	+++	0	0	0	0	Same wallboard being used today equals same price.
Stakeholder Attitude	+++	--	+	--	--	**BSC =** construction industry believes they have proper site control, but the amount of clean wallboard sheets entering waste facilities indicates better site controls is needed. **PTOS** = delivery and on-site storage of wallboard is done properly on most construction sites, rarely does significant damage occur. **SS** = general construction industry is hesitant to implement source separation programs because of the extra time needed to separate wallboard from other waste as well as the extra cost to transport this waste to a recycling facility. Companies that specialize in LEED projects have already accepted this waste reduction initiative in everyday

						operations. **LFT** = most individuals in the construction field will not be accepting of this behavior because it will cost them more money and/or time. Individuals who will be accepting of this change will be wallboard recyclers and companies who work on LEED projects.
Stakeholder Participation	---	++	+	+	++	**BSC** = there seems to be a lack of communication between the contractor and wallboard hanger due to the sheer quantity of wallboard waste being produced. Therefore, better communication is needed between these two stakeholders if this behavior is going to be successfully implemented. **PTOS** = increase communication is needed if further improvement in wallboard delivery and on-site storage is to occur. **SS** = will promote some discussion within the construction industry regarding, which source separation programs are the best for the industry as well as who is willing and what is the financial cost for disposing this waste. **LFT** = will promote discussion with recyclers and contractors to meet disposal agreements that are reasonable as well as highlight waste reduction initiatives that can be implemented.
Education	---	--	+++	--	--	**BSC** = greater knowledge is needed if project sites are going to be run effectively. **PTOS** = already are knowledgeable about proper delivery and on-site storage. **SS** = greater knowledge is needed about the different source separation programs available and how to best separate this waste. **LFT** = landfill tipping fees are cheap so construction industry has never learned to adopt proper waste reduction strategies and diversion programs.

Employment	+++	--	-	+	+	**BSC** = with proper site management better behaviors (handling and installation) will be implemented, which will decrease wasteful use of wallboard and in turn lessen the need for the product -less manufacturing means fewer employees. **PTOS** = Although delivery and on-site storage for the most part is done well if further improvements were made, decreases in wallboard handling will transpire, which will lead to less manufacturing meaning fewer employees. **SS + LTF**= increase employment at recycling facilities.
System Vulnerability	++	+++	+	+++	+++	**BSC** = effective site control leads to less waste, which will improve the functioning of the wallboard system. **PTOS** = effective handling will lead to even less new wallboard waste, which will improve the functioning of the wallboard system. **SS** = diversion of wallboard away from landfills and to recyclers will improve functioning of the wallboard systems since material cycling is occurring. **LTF** = better waste prevention measures and greater diversion of wallboard away from landfills will improve functioning of the wallboard systems since material cycling is occurring.
Product Uncertainty	+++	0	0	0	0	No adding of additional chemicals to the product.
Regulations	++	-	INA	++	-	**BSC + PTOS +LTF**= no regulation in place **SS** = Ministry of Environment (MOE) - 3R's Regulations (102/94) requires the diversion of wallboard waste away from landfills and to recycling facilities (applies to projects over 2,000 square meters and clean wallboard waste).
Enforcement	---	N/A	INA	---	N/A	**BSC + PTOS + LTF** = with no regulation in place there can be no enforcement.

						SS = due to a lack of funding, MOE is not enforcing the 3R's regulations.
Product Donation	+	0	0	++	++	**BSC + PTOS** = will have no impact on donation. **SS + LTF** = will first try to donate clean wallboard waste before sending it for recycling.
Donation Restrictions	--	N/A	N/A	--	++	**BSC + PTOS** = will have no impact on donation restrictions. **SS + LTF**= must be clean and at least half the original panel size.
Service Availability	++	0	0	++	+	**BSC + PTOS** = These behaviors do not impact the adding of additional services. **SS** = if general construction industry was more accepting of this behavior, a greater number of services would appear to help divert this waste to recyclers. **LTF** = if more individuals in the construction industry decide to avoid disposing their waste in landfill because of increase tipping fees more services will appear.
Material Breakdown	---	0	0	-	-	**BSC + PTOS** = no impact on material breakdown. **SS** = with this approach wallboard will never breakdown naturally since it will be recycled every time. **LTF** = if wallboard is recycled it will never naturally break down since it will go for reprocessing before it gets to that stage.
End Life of Product Management • *Reduce* • *Reuse* • *Recycle*	 --- -- ---	 +++ +++ 0	 + 0 0	 0 ++ +++	 ++ ++ ++	**BSC** = this behavior uses multiple reduction strategies to reduce (informing crew design changes, elimination of ordering errors, and better planning) and reuse (use of off-cuts) wallboard. **PTOS** = better handling will lead to a reduction in new wallboard waste generation totals, but will have no impact on reuse or recycling. **SS** = source separation will encourage material donation and recycling of all wallboard waste that is nonhazardous. **LTF** = this behavior tries to encourage the

						construction industry to adopt the waste minimization approaches of reduce, reuse, and recycle by increasing landfill tipping fees.
Future Consideration	--	+++	+	+++	+++	**BSC** = improving all aspects of on-site management will result in wallboard being used to its full potential. Better site control will lead to decreases in manufacturing levels and landfill disposal totals, which will have a positive impact on the future. **PTOS** = reduction in material use from appropriate handling means decreases in manufacturing levels and landfill disposal totals, which will positively impact the future. **SS** = will have a positive impact on future generations because less mineral extraction will happen – the recovered minerals from wallboard recycling will be used in the manufacturing of new wallboard. Furthermore, less wallboard waste will be landfilled. **LTF** = will have a positive impact on future generations because it will encourage some individuals in the construction industry to adopt better waste minimization techniques in order to avoid higher landfill disposal costs. With the implementation of these minimization techniques it will lead to better product use, material donation, and promotion of wallboard recycling.
Holistic Understanding	-	++	+	++	++	**BSC** = understanding how the construction site functions will highlight areas that need improvement, which will in turn increase understanding of wallboards functioning. **PTOS** = reduction in new wallboard waste creation will lead to improve system functioning. **SS** = with source separation there will be greater understanding of wallboard recycling, which will positively impact this system's functioning. **LTF** = by forcing higher disposal fees greater understanding of the system functioning will

						transpire because the construction industry will want to try to find alternatives ways to combat this excess disposal cost.

Key: --- = extremely negative --= negative - = somewhat negative
0 = neutral + = somewhat positive ++ = positive +++ = extremely positive
N/A = Not Applicable INA = Information not Available

8.4.2.3.5 Concluding Remarks and Recommendations for Construction Phase Changes

The ratings found in table 8.5, illustrated not only a greater discrepancy between each option recommended, but also varying degrees of behavior implementation. After evaluating the chart, better site control is required. If this option is implemented, reductions in wallboard waste totals would be realized. This would lead to a number of positive impacts, which include ecological, health, energy consumption, and resource availability. However, with these positive impacts also come negative impacts, which include acceptance, participation, education, and employment. Even with these drawbacks, the positives still far outweigh the negatives. In terms of poor transportation and on-site storage, the construction industry and transporters are doing an acceptable job in eliminating excess waste. It is evident from the ratings and discussion with waste processors that more source separation programs are needed. The benefit of implementing a source separation program(s) is that a higher level of waste will be diverted away from landfills. This option will reduce the adverse environmental impacts that are connected with wallboard use. The unfavorable trade-offs that result with this benefit include added time to separate the materials from one another, unwillingness to adopt these program(s), extra transportation cost to bring this waste to a recycling facility, and further education needed about proper source separation program(s). In evaluating landfill tipping fees, the results indicate disposal fees are too low. If wallboard management is going to improve, increasing tipping fees at landfills will have to occur. Higher landfill disposal fees will force this industry to reduce wasteful practices and identify alternative disposal options. Assessing these ratings has led to a number of feasible recommendations which will not only reduce wallboard waste generation totals, but also divert the remaining waste into more environmentally appropriate disposal paths.

- Better communications should occur between the general contractor and the sub trades.
- Educational programs should focus on teaching contractors and crew members the techniques needed to have effective and open communication. These educational programs should be made available to all interested stakeholders.

- Better transportation practices should be utilized with wallboard delivery. These improvements should include improve material fastening (to prevent material movement) and better product stacking (to thwart material toppling).
- If on-site storage of wallboard sheets has to happen, it is important that the wallboard sheets should be covered to protect them from the outside elements and should be brought to a location with low traffic flow.
- The construction industry should be educated about the different source separation programs that exist.
- Before any source separation program is selected, consideration should be given about the project type and what the local conditions of the area are.
- Enough resources, time, and energy should be spent in developing source separation program(s) that will work best for wallboard waste in Southern Ontario.
- The construction industry should be educated about the importance of not cross contaminating designated waste bins.
- The construction industry should first donate and/or reuse any clean wallboard sheets and/or scraps (as long as scraps are at least half the size of the original panel) before they are sent for recycling.
- Transfer stations and landfills should have designated wallboard waste bins on-site (one source separation program stakeholders can use if they do not want to create their own).
- Tipping fees should double in order to deter the construction industry from discarding its waste in landfills. With such a significant economic disincentive in place, it will force this industry to eliminate wasteful practices and/or implement source separation programs.
- Partnerships and financial agreements should be made between construction companies, wallboard suppliers, and recyclers. These partnerships should involve wallboard manufacturers accepting to use reprocessed gypsum minerals in new wallboard, wallboard recyclers decreasing tipping fees to

encourage wallboard recycling, and construction companies willing to discard uncontaminated wallboard waste loads (combination of clean and contaminated wallboard scraps) at recycling facilities for this decreased disposal fee.

- A directory of construction recyclers in Ontario should be created and be easily accessible to all stakeholders.

8.4.3 Product Specific Waste Minimization Strategies

There are a number of waste prevention strategies that can be tailored towards improving the wallboard situation. These methods include: better product redesign; increase in educational programs; the use of a just-in-time delivery approach for incoming wallboard; make wallboard manufacturers more accountable for their products and their prices; and stricter regulations and better enforcement.

8.4.3.1.1 Product Redesign

Product redesign is the process of revamping a product to make it better. If product redesign occurs, not only can a product's lifespan increase, but the product can be redesigned for easier repair and reuse. There are a number of modifications that can be made to a product to reduce the amount of waste it generates. These design steps include 1) using recycled materials in the construction of the product, 2) encouraging easy product disassembly, 3) increasing the lifespan of product by not only making the product more structurally sound, but also using materials that are known to last longer, and 4) designing the material for easy reuse and/or recycle (Leverenz, 2002; Public Works and Government Services Canada, 2000). Product redesign is about changing manufacturer's practices with the end goal being a new product that is better for the environment.

In redesigning wallboard, a number of potential product modification steps could be taken. These changes include using paper backing made from recycled paper, using more recycled gypsum minerals in the wallboard core, increasing the lifespan of wallboard by injecting the sheets with various fire, mold, and moisture resistant chemicals, creating wallboard sheets that use either a tongue and groove or a joiner strip connection system in order for easier disassembly, and finally developing the techniques and technologies to make this material easier to reuse and recycle. Some of the design changes have begun. Recycling technology allows 20% of new wallboard to be made from recovered gypsum processed at the NWG facility (see Appendix G). Furthermore, Certainteed, a wallboard manufacturer is using NWG recovered gypsum minerals in the manufacture of their new wallboard (New West Gypsum Employee, 2009). Wallboard lifespan is also increasing due to improvements in product durability. Wallboard has become more durable through the injecting of various chemicals on the panels to make them more resistant to fire, mold, and moisture (New West Gypsum Employee, 2009; Sittler, 2009; Waring, 2009). What these behaviors illustrate, are wallboard manufacturers are moving in the right direction in reducing wallboard waste creation totals, but that these actions are increasing the cost of wallboard.

8.4.3.1.2 Educational Programs

A substantial amount of wallboard waste is created by wallboard hangers who use faulty practices. This lack of education on proper installation techniques and disposal options are other areas where improvements in waste reduction and diversion behaviors could be realized (Gere, 2009; Horvath, 2004; New West Gypsum Employee Interview, 2009; Recycling Council of Ontario, 2005; Yahya and Boussabaine, 2006).

Most waste processors (see Appendix G) believe that the construction industry has a good understanding regarding wallboard management, but that further education is needed (Arsenault, 2009; Waring, 2009). Most interviewees said “no” when asked whether this industry is educated on the different disposal avenues for wallboard waste. This industry’s lack of awareness is illustrated by the fact that most wallboard waste in Southern Ontario is discarded in landfills (Arsenault, 2009; New West Gypsum, 2009; Sittler Employee, 2009; Waring, 2009). Only certain groups within the construction industry seem to be educated on the different disposal paths, such as companies that focus on LEED projects and whose people know about wallboard recyclers and other C&D recyclers (Sittler, 2009). Unless a construction company is in the area of a wallboard recycler, these facilities tend not to be used by the general construction industry (Arsenault, 2009; Sittler Employee, 2009; Waring, 2009).

The above beliefs were somewhat validated by the general contractors (see Appendix I) when asked to identify wallboard recycling facilities in Southern Ontario. Although company names were given, these individuals showed some uncertainty in their responses. Apprehension existed because they were unsure if these facilities still existed and/or recycled wallboard waste (Greyhound Employee, 2009; Keating, 2009). In the case of the wallboard hanger (see Appendix H), he immediately identified the main wallboard recycler in Ontario. Because his company focused on LEED projects, he needed to know the facilities in his area that recycle wallboard waste (Rosmar Employee, 2009). What this illustrates is a lack of awareness by the construction industry and a lack of promotion by wallboard recyclers.

General contractors and the sub-contractor were unaware of any adverse impacts connected with landfilling wallboard waste (Greyhound Employee, 2009; Keating, 2009; Rosmar Employee, 2009). When asked whether this industry needs additional education, two out the three people indicated “yes”. Awareness of waste reduction initiatives and better knowledge about the different wallboard waste disposal paths were the two areas highlighted (Greyhound Employee, 2009; Rosmar Employee, 2009). Finally, Mr. Gere stated that the construction industry needs better education when it comes to installing, handling, and disposing of wallboard waste (Gere, 2009).

Wallboard hangers need to be given the opportunity to attend educational classes that center on topics such as waste reduction strategies, wallboard reuse and donation programs, proper handling techniques, and environmentally appropriate disposal methods. The implementation of these educational programs will not only reduce wallboard waste generation totals, but also result in better management of waste that is being produced. This strategy prides itself on providing crew members with a toolbox of waste reduction methods and environmentally appropriate disposal options (Dainty and Brooke, 2004). Wallboard hangers need to be educated and know this information, but unfortunately this information is not given to them. Therefore, provincial government along with wallboard manufacturers and waste processors should come together to teach the construction industry about what behaviors they should employ to improve their current techniques.

8.4.3.1.3 Just-in-time Delivery

Waste generation totals could be reduced if a just-in-time delivery system was implemented. With materials spending less time on-site there is less risk of the materials being damaged due to exposure to the weather and/or accidental damage (Dainty and Brooke, 2004). If this strategy was used for wallboard, positive changes in waste generation totals could be experienced (Greyhound Employee, 2009; Keating, 2009; Rosmar Employee, 2009). Recommending a just-in-time delivery approach as one option to improve wallboard waste management in Southern Ontario is not needed, since this behavior has been readily accepted and used.

8.4.3.1.4 Extended Producer Responsibility and Full Cost Pricing

Extended producer responsibility and full cost pricing are two further strategies that could lead to better management of wallboard waste (Leverenz, 2002; Skitmore et al, 2006). Although these two strategies do not directly deal with reducing wallboard waste totals, they do center on making the industry more accountable. By making the industry more responsible, it indirectly influences wallboard waste generation totals. If wallboard manufacturers were responsible for their product throughout its entire life, definite modifications would occur to facilitate easier management. By placing the responsibility on producers, wallboard products will be better designed. This design will lead to increased lifespan, greater reuse options (donation and disassembly/reassembly), higher durability, and improved recycling capabilities (Leverenz, 2002). All of these actions will limit the amount of wallboard waste being produced while at the same time encourage better disposal options.

Wallboard prices are calculated based on profit and the manufacturers' estimations of how much the product cost them to produce. These prices are not a true representation of the financial costs and environmental impacts that arise, but rather an estimation of how much it costs the wallboard manufacturer to make, which results in deflated wallboard prices (Skitmore et al, 2006). If wallboard prices took into account the direct and indirect ecological impacts that arise with this product throughout its entire life, wallboard prices would be much higher (Skitmore et al, 2006; Yahya and Boussabaine, 2006). With higher prices will come less willingness by the construction industry to participate in wasteful wallboard practices.

8.4.3.1.5 Stricter Regulations and Better Enforcement

Stricter regulations and better enforcement of existing laws are two additional options that could improve wallboard management as well as enhance the diversion of wallboard away from landfills. As already discussed in Chapter 4 sections 4.5 *Ontario Regulations Pertaining to CRD Waste* and 4.5.1 *3R's Regulations* and heard by waste processor interviewees (see Appendix G), there are three main regulations that the construction industry follows regarding the management of materials and their disposal. The intentions of the 3R's regulations are to minimize waste and maximize diversion. Unfortunately, the problem with these regulations are the loopholes in their requirements (only applies to projects with a floor area over 2,000 square meters (m^2) and contaminated materials are allowed to be landfilled) and limited enforcement by the Ministry of the Environment (MOE) (Arsenault, 2009; Recycling Council of Ontario, 2005; Saotome, 2007; Waring, 2009).

Waste processors believe that if the 3R's regulations would be modified to eliminate these loopholes and/or new regulations would be created and better enforced, better wallboard reduction initiatives and diversion practices would happen. They highlighted regulation implementation and stricter governmental enforcement as the two behaviors that have shown success in improving the construction industry's practices (Arsenault, 2009; Sittler, 2009; Waring, 2009). Although the construction industry feels that it is already regulated too much by the Ontario government, the evidence indicates otherwise. Discussions with waste processors and a review of the literature both identify weak regulations and a lack of regulation enforcement as playing a significant role in why wallboard waste, that should be recycled, is continuing to be landfilled (Arsenault, 2009; Recycling Council of Ontario, 2005; RIS International Ltd. 2005; Saotome, 2007; Sittler, 2009; Waring, 2009). Better monitoring by the MOE is needed. Furthermore, there needs to be stronger communication between the municipalities and the provincial government. Municipalities are the eyes of the provincial government, since they witness firsthand the type of waste which is being discarded in their landfills. If there was an open line of communication between the two, the province would be more aware of how well their regulations are being followed and whether further enforcement is needed.

Table 8.6 Evaluation of product specific phase changes using the sustainable IWM criteria

Change in Practices Category							
Evaluation Tools (Criteria)	**Product Specific Phase Changes**						
	Current Wallboard Situation (Base Case Scenario)	**If Recommended Behaviors was Implemented**					
		Product Redesign (PR)	Educational Programs (EP)	Just-in-time Delivery (JD)	Extender Produce Responsibility and Full Cost Pricing (ERFP)	Stricter Regulations and Better Enforcement (SRBE)	Justification for Rating
Environmental Impacts with Current Behavior • *Land* • *Water* • *Air* • *Habitat disturbance and modification* • *Species disturbance and biodiversity loss*	 --- --- --- -- --	 +++ +++ -/++ +++ +++	 +++ +++ +++ +++ +++	 0 0 0 0 0	 +++ +++ -/++ +++ +++	 ++ ++ ++ ++ ++	**PR** = redesigning wallboard will lead to lower manufacturing (increase lifespan/less wear and tear) and disposal totals (disassembly), but higher recycling. However, by making the panels more durable air quality will negatively be affected due to the injection of chemicals. **EP** = If the industry was better educated on proper handling, installation, and disposal techniques, reductions in wallboard wastage and diversion wallboard away from landfills will occur. **JD** = this behavior is already being used by the construction industry and therefore, will have the same ecological impacts. **ERFP** = By holding manufacturers more accountable for their product and having them determine the true cost their product has on the environment, it will lead to better product design and less waste due to increase cost. These actions will positively influence the ecological system (adding of chemicals will reduce air quality).

							SRBE = these regulations require all large project (projects over 2,000 square meters) to develop a waste reduction work plan and identify facilities in the area that recycle wallboard waste. A lot of smaller projects are excluded from the 3Rs regulations. Furthermore these regulations are rarely enforced by the MOE. If these regulations applied to all projects and were enforced, ecological impacts will be reduced.
Health Impacts	---	-/++	-/+++	0	-/+++	-/+++	**PR** = most health problems will be reduced because there will be less manufacturing and disposal totals. However, there will be the adding of synthetic chemicals to increase panel durability and increases in dust/particle generation because of disassembly/recycling, which will negatively impact air quality. **EP** = health problems will be less because manufacturing and disposal totals will be lower due to the implementation of better practices and any generated waste will be diverted away from landfills. However recycling will lead to increase dust/particle generation, which adversely impacts human respiratory system, eyes, skin, and nose. **JD** = behavior is already being used by the industry and therefore, no added health impacts. **ERFP** = most health problems will be less because better design will extend wallboard's life (decease disposal levels) and increase cost, which will deter wasteful behaviors from continuing (less manufacturing of products). However, by making the panels more durable added chemicals will decrease air quality. Furthermore, recycling will lead to increase dust/particle generation, which adversely impacts human respiratory system, eyes, skin, and nose. **SRBE** = increased regulations and better enforcement will reduce health problems because industry will be forced to use waste minimization strategies to better manage wallboard materials. However recycling will lead to increase dust/particle generation, which adversely impacts human respiratory system, eyes, skin, and nose.
Energy Consumption	---	+++	+++	0	+++	0	**PR** = energy consumption will be less because manufacturing totals will be lower due to increase lifespan and the ability to dissemble and reuse the panels in a new area.

							EP = better education on installation techniques will lead to the use of less wallboard which will result in lower manufacturing levels. **JD** = behavior is already being used by industry therefore same consumption levels will be experienced. **ERFP** = energy consumption will be less because manufacturing totals will be lower due to increase panel lifespan and higher costs (full cost pricing). **SRBE** = does not deal with the manufacturing of wallboard only deals with the end life management of wallboard.
Resource Availability	+++	+++	+++	0	+++	++	**PR** = a lower amount of gypsum minerals will be needed because manufacturing totals will be reduced, plus recycling these panels will allow the recovered gypsum minerals to be used in new wallboard manufacturing. **EP** = with the construction industry being better educated it will lead to the adoption of waste prevention strategies, which will decrease the need for raw gypsum minerals – less waste of materials and the recovering of gypsum minerals that will be used in the manufacturing of new wallboard. **JD** = behavior is already being used and therefore, same amount of gypsum minerals will be used. **ERFP** = a lower amount of gypsum minerals will be needed because manufacturing totals will be reduced due to increase cost and higher lifespan. In addition panels will be better designed for easier recycling, which will allow recovered gypsum minerals to be used in new wallboard manufacturing. **SRBE** = wallboard waste will be recycled and recovered, gypsum minerals can be used in the manufacturing of new wallboard.
Travel Distance (rating based on use and disposal)	++	-/+	-/+	0	-/+	-/+	**PR** = travel distance will negatively be influenced since fewer wallboard recyclers are in the province. This will result in greater distances being traveled to unload this waste. However, with wallboard being better design it will reduce its chances of being damaged because of wear and tear, which will reduce the need to buy wallboard and in turn lessen the impact it has on travel distance. **EP + ERFP+ SRBE** = further distances will be traveled to dispose of this waste, but less wallboard will need to be

							purchased due to better education and regulations, which will reduce added transportation cost associated with this material if these behavioral changes had not been implemented. **JD** = will not impact on travel distance since wallboard will be sold and disposed of in the same locations.
Product Functionality • *Durability* • *Aesthetic Appeal* • *Maintenance ease* • *Installation ease*	 - +++ +++ +++	 +++ 0 0 -	 0 0 0 0	 0 0 0 0	 +++ 0 0 --	 0 0 0 0	**PR + ERFP**= designing a product to be stronger and more resistant to the elements leads to higher durability. Furthermore, designing wallboard that can easily be dissembled will result in greater installation difficulty. **EP +JD + SRBE**= will not have an effect because wallboard is not physically being changed.
Product Rating • *Insulation* • *Noise Resistant* • *Fire Resistant* • *Mold Resistant* • *Moisture Resistant*	 + - - -- --	 +++ +++ +++ +++ +++	 0 0 0 0 0	 0 0 0 0 0	 +++ +++ +++ +++ +++	 0 0 0 0 0	**PR** = with the adding of addition materials an increase in product rating will occur. **EP + JD + SRBE** = will not have an influence because wallboard is not physically being changed. **ERFP** = if manufacturers are held responsible for their product, they will manufacture panels with higher ratings in order to increase lifespan of the product. By increasing the lifespan they will not have to deal with the management of these panels as often. Because manufacturers will design wallboard that is demountable, installation of this wallboard will be more difficult.
Product Availability	+++	0	0	0	0	0	Will have no impact on product purchasing since wallboard will continue to be sold in the same locations.
Affordability	+++	---	0	0	---	0	**PR** = by making a premium product (increase lifespan, made from recycled waste, disassembly capabilities) a higher price will transpire. **EP + JD +SRBE =** same wallboard being used today equals same price. **ERFP** = Higher purchasing price will not only make a premium product (increase lifespan, disassembly capabilities), but one that represent the true cost of making that product.
Stakeholder Attitude	+++	-/+	-/++	0	---	-/+	**PR** = Manufacturers have just started to redesign wallboard panels to have higher durability, disassembly capabilities, and made from recycled materials. However the construction industry has for the most part not accepted these panels because of the added cost.

							EP = Mixed emotions on whether additional educational programs are needed. Literature and most interviewees say further education will lead to better handling, installation, and disposal techniques. However, others have said no extra education is warranted. **JD** = already a high familiarity with this behavior. **ERFP** = Wallboard manufacturers will reject this behavior because it will impact their bottom line. By making them accountable for their product's entire life results in extra disposal burdens, which they never had before and additional financial cost. **SRBE** = mixed emotion towards the 3 Rs regulations and its enforcement. Construction industry feels they are regulated too much and that these regulations are heavily being enforced. On the other hand, although waste processors are accepting of these regulations they feel that they are too weak and better enforcement is needed.
Stakeholder Participation	---	++	+++	0	+++	+	**PR** = this option will lead to open discussion between wallboard manufacturers and recyclers. These discussions will center on how to redesign wallboard for easier recycling and how to add higher percentage of recycled gypsum in new wallboard. Furthermore discussion will take place between construction industry and recyclers about diverting wallboard away from landfills. **EP** – with educational programs in place communication will transpire. **JD** = will have no impact on increasing communication since it is already being implemented well. **ERFP** – With greater responsibility on manufacturers to ensure better management of wallboard (throughout its entire life), greater communication between the construction industry, wallboard recyclers, and manufacturers will need to take place to make the necessary changes. **SRBE** = If these regulations were better enforced a greater amount of communication will transpire.
Education	---	--	--	0	---	-/+	**PR** = manufacturers are at the beginning stages of wallboard redesign, greater education is still needed to make these panels

							better. **EP** – stakeholder's knowledge about proper handling, installation, and disposal techniques is relatively low due to the quantity of wallboard waste being generated on-site. Therefore, further education is needed to help highlight and implement appropriate behaviors from inappropriate ones. **JD** = behavior already being implemented well. **ERFP** = Because current wallboard prices are not a true representation of the cost wallboard plays on the environment, it illustrates a lack of knowledge by these manufacturers regarding the impacts their product has on the environment and human health. **SRBE** = government and construction industry are not enforcing or following the 3Rs regulations. Therefore these actions show a lack of knowledge on the stakeholder part. Waste processors are aware and know of these regulations.
Employment	+++	---	--	0	-/+	++	**PR** = with better design not only will it lead to panel reuse, but also increase panel durability. With panels lasting longer less manufacturing of new products is needed and therefore, the employment of less individuals. **EP** = better education will lead to the implementation of better behaviors (handling and installation), which will decrease wasteful use of wallboard and in turn lessen the need for the product -less manufacturing means fewer employees. **JD =** same wallboard behavior being used today equals same level of employment. **ERFP** = increase product life and disassembly capabilities are all actions that will reduce manufacturing of wallboard, which will lead to fewer jobs. However, because manufacturers will be more accountable for their waste it will create new jobs (creation of more recycling facilities) **SRBE** = need to hire more MOE officers to enforce regulations. Recycling companies will also have to employ more workers because of increase disposal totals.
System Vulnerability	++	+++	++	0	+++	+	**PR + ERFP** = improving the design of wallboard comes easier recycling of this material and increase lifespan, which enhances the overall functioning of the system by increasing its efficiency

							(material cycling). **EP** = by educating the industry a greater understanding of how the system operates will transpire, which will have a positive influence on the system's functioning. **JD** = same wallboard behavior being used today equals same product functionality level. **SRBE** = this behavior tries to encourage better disposal practices, which will have a positive impact on the end-life of wallboard waste.
Product Uncertainty	+++	--	0	0	--	0	**PR + ERFP** = the addition of synthetic chemicals to the panel will increase the panel durability. **EP + DJ + SRBE** = no adding of additional chemicals to the product.
Regulations	++	+++	++	0	--	++	**PR** = Ontario Ministry of Municipal Affairs and Housing Regulation 403/97 Section 2 – regulated the use of reusing materials. **EP** = MOE Regulation 103/94 – require companies to offer educational programs to their employees about source separation programs. **JD** = this option is already being used by the construction industry therefore; there is no need for the implementation of a just-in-delivery regulation. **ERFP =** no regulation in place. **SRBE** = there are a regulations in place when it comes to wallboard disposal practices, but it only applies to large scale structures.
Enforcement	---	+++	---	N/A	N/A	---	**PR + SRBE** = regulation is somewhat being enforced. **EP** = lack of funding has resulted in the MOE not enforcing this regulation. **JD + ERFP**= no regulations and therefore, no enforcement.
Product Donation	+	0	++	0	++	++	**PR + JD** = will have no impact on donation. **EP** = as a way to divert waste away from landfills, some educational programs will focus on wallboard donation. **ERFP** = to help manage clean wallboard waste manufacturers can divert this waste to donation centers. **SRBE** = one component of these regulations is the development

							of a work reduction plan. One action that can be taken is wallboard donation.
Donation Restrictions	--	N/A	--	0	--	--	**PR + JD** = will have no impact on donation restrictions. **EP + ERFP+ SRBE** = must be clean and half the original panel size.
Service Availability	++	++	++	0	+++	+++	**PR** = with this product being designed for easier recycling more services will appear. **EP** = because educational programs will focus on waste diversion, greater number of services will appear. **JD** = this behavior does not impact the adding of additional services. **ERFP** = manufacturers will be forced to deal with the end life of wallboard and therefore, greater services will need to be establish to handle all this waste. **SRBE** = regulations will force diversion, which will result in the need of more services to dispose of this waste.
Material Breakdown	---	-/0	-/0	0	-/0	-/0	**PR + EP + ERFP + SRBE** = if paneling is recycled it will not naturally breakdown since it will be reprocessed before it has a chance. However, if this paneling is landfilled it will eventually breakdown on its own. **JD** = no impact on material breakdown.
End Life of Product Management • *Reduce* • *Reuse* • *Recycle*	 --- -- ---	 0 ++ +++	 +++ +++ +++	 0 0 0	 +++ +++ +++	 ++ ++ +++	**PR** = if panels are designed for easier disassembly it will allow for greater panel reuse. Furthermore, designing wallboard so it can be easily recycled is a further waste minimization behavior this option is able to implement. **EP** = by offering educational programs, information will center on improving the overall management of wallboard through the implementation of waste minimization strategies. **JD** = waste minimization strategies of reduce will not be impacted since this behavior is already being well used by the industry (reuse and recycle do not apply to this behavior). **ERFP** = full cost pricing will force construction industry to adopt better installation techniques to reduce excess wallboard waste. Manufacturers will design wallboard that can be dissemble to increase wallboard's lifespan as well as continue to reuse the panels. Finally, this option makes manufacturers deal with the waste. By making them responsible they will divert this waste to

							recycling centers for disposal. **SRBE** = these regulations encourages the reduce and the reuse of wallboard waste before recycling.
Future Consideration	--	-/++	+++	0	-/++	++	**PR + ERFP** = increase lifespan and making the panels easier to recycle will have a positive impact on future generation. However, the adding of additional chemicals will have a negative impact. **EP** = with the adoption of waste minimization strategies, not only will less wallboard waste be produced, but better disposal options will be encouraged (recycling). **JD** = same behavior being used today equals same impact on future generations. **SRBE** = less waste going to the landfill and the reuse of recycled gypsum minerals in the manufacturing of new wallboard will have a positive impact on future generations.
Holistic Understanding	-	++	++	0	++	+	**PR**= with panel redesign, a better understanding about the various interactions that are involved with wallboard functioning will transpire in order to redesign this product better. **EP** = with education, better understanding will transpire about the interaction that take place within the wallboard sub-systems (manufacturing, on-site, and disposal). Having this knowledge will lead to better functioning of this system. **JD** = will not provide any additional insight regarding wallboard functioning. **ERFP** = with better design and awareness of the full cost a panel has on the environment and human health, it will lead to positive understanding of how this system functions and where improvements can be made. **SRBE** = better understanding of how waste minimization techniques can be used to reduce wallboard waste generation totals will bring greater awareness on how this system operates (specifically material cycling).

Key: --- = extremely negative --= negative - = somewhat negative
0 = neutral + = somewhat positive ++ = positive +++ = extremely positive
N/A = Not Applicable INA = Information not Available

8.4.3.1.6 Concluding Remarks and Recommendations for Product Specific Phase Changes

Table 8.6 illustrates that all but one of the recommended options need some sort of implementation in the future. The results indicate that product redesign, educational programs, and extended producer responsibility and full cost pricing are for the most part, not being used. If these options were employed, significant improvement in wallboard management and disposal techniques would be experienced, as describe in the above sections. The trade-off with using these waste prevention behaviors is the unwillingness by the construction industry to accept these changes and the extra time and cost that would incur from their implementation. The ratings found under the just-in-time delivery category, demonstrate that this behavior is already being employed to the best of the industry's ability and therefore there is no need for change. In the stricter regulations and enforcement section, it is evident that regulations exist but that they are loophole prone and lack proper enforcement. If these regulations were modified and better enforced, improvements in wallboard management and disposal would be experienced. However, a trade-off with developing stricter regulations and enforcing them is resistance from the stakeholders who are going to be directly affected by the new regulations. Furthermore funds will be diverted away from other programs in order to hire extra personnel for enforcement.

After evaluating each option and its rating, there are a number of recommendations that can be offered:

- Wallboard manufacturers should use a greater percentage of recycled gypsum wallboard minerals and recycled paper in the manufacture of new wallboard
- More materials (resistant properties, gypsum) should be added to all wallboard panels to make these panels stronger and more resistant to the outside elements.
- Better fastening methods should be employed (tongue and groove and/or reversible) when installing wallboard to limit the use of tape, nails, and/or screws and increase the probability of being dissembled in the future.
- More educational resources should be directed towards the construction industry, especially when it comes to waste reduction strategies, wallboard

reuse and donation programs, better ordering techniques, proper handling/installation practices, and environmentally appropriate disposal methods.

- Waste processors should educate wallboard users about the recyclability of wallboard, where recycling facilities exist, and what sellable material these recovered minerals can be turned into.
- More responsibility should be placed on manufacturers regarding the use and disposal of their product.
- The price of wallboard should increase to represent its true cost by increasing the tax on this material.
- The 3R's regulations should be modified to eliminate any loopholes that exist.
- The MOE should better enforce the regulations that are already established.
- A universal waste regulation should be instituted with regards to the construction industry's waste disposal practices.
- A special call line should be created so municipalities and watchdog groups can report poor construction waste disposal practices to the MOE.
- Municipal landfills in Southern Ontario should work together to create a landfill ban on wallboard waste. Before this ban can be implemented, alternative disposal options need to be well established and the construction industry needs to be educated on these alternatives.
- Travel distance (under 230 kilometers) should be considered when determining the disposal route for wallboard.
- Laws should be established to prohibit construction waste from being transported to the United States for disposal.
- Better communication should exist between the provincial government and the municipalities.
- The provincial government should encourage and provide incentives to recycling companies within Ontario.

8.5 Summary

The focus of this chapter was to evaluate gypsum wallboard products and to compare them to composite panels and to determine which product is more environmentally friendly. The comparison between these two products was done using the sustainable IWM criteria for alternative materials. After a detailed examination of each product, it was clear that a number of benefits and limitations exist with each. The ratings from the criteria set did indicate wallboard as being the best wall product in use today. The main problem with using wallboard is that it is not being managed appropriately. Therefore, further attention must be directed towards implementing better handling and disposal techniques. The second part of this chapter was dedicated to highlighting management practices that could lead to the management of wallboard in a more environmentally appropriate manner. These practices focused on wallboard waste minimization and diversion strategies. Each option suggested was evaluated using the sustainable IWM criteria for change in practices. Option ratings were done in order to determine which options should be recommended for implementation in the future.

Chapter 9 Recommendations and Conclusions

The purpose of this research was to determine what options were the most desirable and feasible to deal sustainably with gypsum wallboard waste in Southern Ontario now and in the future. In order to answer the research question a number of sub questions were answered.

The first question required investigating how gypsum wallboard is managed in Southern Ontario, and whether any problems exist. Through a preliminary review of the literature and discussion with local waste processors, the information collected indicated that problems exist with wallboard management and that further research should be dedicated to this issue (see section 1.3). The narrowness of this topic made it a challenge to find resources dedicated to wallboard specifically. Consequently, much of the background information collected for this research focused on construction waste. The information acquired from this review helped illustrate the damaging impacts that improper wallboard management has on the environment – mineral extraction, release of hydrogen sulphide gas, leaching of metallic sulphide into groundwater, and so forth (see section 5.4). Furthermore, this review not only offered insight about why some construction waste/wallboard waste is not managed appropriately (see sections 4.3.2, 4.4.1, 4.5.1 and 5.8.1), but also provided some generic recommendations on how to improve problematic construction waste/wallboard waste (see sections 4.3.3, 4.6, 5.6, and 5.8.2). Acquiring this background information was necessary in establishing what the current situation was and what needs to be done to improve it.

The second question dealt with creating a criteria set that would be used to evaluate the recommended options. Incorporating the concepts of sustainability (see section 3.2) with those of integrated waste management (IWM) (see section 3.3), two sustainable IWM criteria sets were developed (see section 3.4). These criteria sets were used to evaluate the feasibility of the recommended options.

The third question focused on uncovering alternative interior wall options that could realistically replace wallboard in the future. After a review of the literature and discussions with individuals in the construction industry, composite panels were determined to be the most feasible interior wall replacement option for wallboard (see section 6.1.1). A lifecycle approach was taken to evaluate the different adverse impacts that arise throughout composite panels' life (see section 6.2). It should be noted that a lifecycle approach was also completed on gypsum wallboard as well (see section 5.4). These lifecycle perspectives were crucial in evaluating the two wall material options against one another using the sustainable IWM criteria (see section 8.3). When these two wall materials were evaluated using the sustainable IWM criteria set for alternative materials, it was determined that wallboard is still the best interior wall option, but that wallboard needs to be better managed.

The fourth question required identification of behaviors that could be adopted to manage wallboard in a more sustainable manner. Research for this question centered on behaviors that have worked in the past to deal with other problematic construction and demolition waste (see sections 4.3.3, 4.6, 5.6, and 5.8.2). Furthermore, discussion with various stakeholders also provided insight on how improvements could be made (see Appendices F, G, H and I). The information they provided assisted in the development of a list of options that concentrated on changing individual and industry practices (see section 8.4). The options recommended were then evaluated using the sustainable IWM criteria set for change in practices.

Responding to the fifth question required taking the recommended options (alternative materials and change in practices) and rating them against the appropriate sustainable IWM criteria set. In terms of alternative materials, the two options were rated against one another on creation, use, and disposal (see section 8.3.3). It was recommended that gypsum continue to be used as the main interior wall option. However, it was determined that improvement in this material management was needed, which led to the identification and evaluation of changes in practices (see section 8.3.4). The recommended changes in practices were grouped into four different sections (design, pre-construction, construction, and product specific). Each behavior in the section was compared individually to the current wallboard situation and rated as if it were implemented today. The criteria set was able to highlight the different degrees of positive and negative impacts that would arise with the implementation of each behavior recommended.

The last question identified the trade-offs that would arise if a particular behavior were implemented (see section 8.4). All of these questions were influential in answering the research question.

9.1 Recommendations

Depicted in table 9.1 are the recommendations offered, the time of implementation (time), how far this recommendation can be used in Ontario (area), whether this recommendation can be applied to other construction and demolition waste (broader application), and sections in the thesis where the recommended option was discussed. In terms of time there are four categories: immediate (within the next three months), near future (within a year), future (within three years), and far future (over five years). Under area, the recommendation can either apply to Southern Ontario or all of Ontario. Finally, with the broader application category, either a yes or no answer is given. Yes indicates the recommendation can apply to management of other construction waste, while no means the recommendation is specific to gypsum wallboard waste management and cannot be applied more broadly.

Table 9.1 The recommendations offered under alternative materials and change in practices and how these recommendations can be used under different circumstances

Recommendations	Time	Area	Broader Application	Section(s) of Where Recommended Option was Discussed in Thesis
Alternative Materials				
Wallboard should continue to be used, but that better waste prevention and diversion techniques should be implemented to lessen the adverse environmental impacts connected with its creation, use and disposal	Immediate	Ontario	No	See chapter 8 sections 8.3.1 *Leaving the Current Gypsum Wallboard Situation Alone;* 8.3.3 *Evaluation of Gypsum Wallboard and Composite Panels Using the Sustainable IWM Criteria;* and 8.3.4 *Concluding Remarks and Recommendations on Gypsum Wallboard and Composite Panels*
Untreated composite panels should be used as an alternative interior wall option in the building of residential homes.	Far Future	Ontario	No	See chapter 8 sections 8.3.2 *Composite Paneling*; 8.3.3 *Evaluation of Gypsum Wallboard and Composite Panels Using the Sustainable IWM Criteria;* and 8.3.4 *Concluding Remarks and Recommendations on Gypsum Wallboard and Composite Panels*
More research and technology should be devoted to developing recycling techniques that can handle treated composite panels.	Far Future	Ontario	No	See chapter 8 sections 8.3.2 *Composite Paneling*; 8.3.3 *Evaluation of Gypsum Wallboard and Composite Panels Using the Sustainable IWM Criteria;* and 8.3.4 *Concluding Remarks and Recommendations on Gypsum Wallboard and Composite Panels*

Change in Practices				
Design Phase Recommendations				
Architects/designers should select wallboard sheet sizes closest to the wall height being constructed to reduce wallboard off-cut totals.	Immediate	Ontario	Yes	See chapter 8 section 8.4.2.1.1 *Standard Size Materials*
Construction industry should encourage custom design practices that focus on minimizing material waste.	Immediate	Ontario	Yes	See chapter 8 section 8.4.2.1.1 *Standard Size Materials*
Improvements in demountable wallboard should be made (to increase strength, remove decorative overlays, and permit easier assembly and disassembly) before these panels are promoted more within the construction industry.	Far Future	Ontario	No	See chapter 8 section 8.4.2.1.2 *Deconstruction*
Education should be available to wallboard hangers regarding the assembly and disassembly of demountable wallboard.	Far Future	Ontario	No	See chapter 8 section 8.4.2.1.2 *Deconstruction*
Architects and builders should select wallboard panels that are more durable, in order to eliminate some of the damage (holes and inability to handle exposure to the elements) that arise with cheaper wallboard products	Immediate	Ontario	Yes	See chapter 8 section 8.4.2.1.3 *Material Selection*
Pre-Construction Recommendations				
Wall installation plans should be prepared prior to an order being made to improve order accuracy and eliminate order errors.	Immediate	Ontario	Yes	See chapter 8 section 8.4.2.2.1 *Planning*
Wallboard hangers should always use a wallboard installation plan. This action will improve the efficiency of wallboard hanging, which in turn will reduce wallboard waste.	Immediate	Ontario	Yes	See chapter 8 section 8.4.2.2.1 *Planning*
Inventory records should be used by all construction and sub trade companies.	Near Future	Ontario	Yes	See chapter 8 sections 8.4.2.2.2 *Up-to-date Inventory* and 8.4.2.2.3 *Accurate Ordering*

Inventory records should be kept up-to-date and they should be reviewed before a material is ordered.	Near Future	Ontario	Yes	See chapter 8 sections 8.4.2.2.2 *Up-to-date Inventory* and 8.4.2.2.3 *Accurate Ordering*
Better communication should be implemented, especially on commercial, industrial, and institutional projects, to inform workers about design changes. The communication can include daily announcements informing all crew members whether design changes have been made, supplying contractor/sub trades with up-to-date designs of the project. Also, better communication between the client, architect, and contractor regarding design changes is needed.	Near Future	Ontario	Yes	See chapter 8 section 8.4.2.2.4 *Correct Design*
Enough notice should be given to sub trades (electricians, framers, plumbers, etc…) to deal with any changes made to the design of a project.	Immediate	Ontario	Yes	See chapter 8 section 8.4.2.2.4 *Correct Design*
Contractual clauses should be used to strengthen the motivations of wallboard hangers to be accountable for their waste practices and poor disposal techniques.	Immediate	Ontario	Yes	See chapter 8 section 8.4.2.2.5 *Development and Enforcement of Contractual Clauses*
Incentives for use of proper installation techniques (reduce waste means less tipping fee) should be used for projects, in which the general contractor is responsible for the disposal of waste.	Immediate	Ontario	Yes	See chapter 8 section 8.4.2.2.5 *Development and Enforcement of Contractual Clauses*
General contractors should encourage wallboard hangers to use their off-cut pieces (half original panels size or larger).	Immediate	Ontario	No	See chapter 8 section 8.4.2.2.5 *Development and Enforcement of Contractual Clauses*
Construction Recommendations				
Better communications should occur between the general contractor and the sub trades.	Immediate	Ontario	Yes	See chapter 8 section 8.4.2.3.1 *Better Site Control*
Educational programs should focus on teaching contractors and crew members the techniques needed	Near Future	Ontario	Yes	See chapter 8 section 8.4.2.3.1 *Better Site Control*

to have effective and open communication. These educational programs should be made available to all interested stakeholders.				
Better transportation practices should be utilized with wallboard delivery. These improvements should include improve material fastening (to prevent material movement) and better product stacking (to thwart material toppling).	Near Future	Ontario	Yes	See chapter 8 section 8.4.2.3.2 *Poor Transportation and On-site Storage*
If on-site storage of wallboard sheets has to happen, it is important that the wallboard sheets should be covered to protect them from the outside elements and should be brought to a location with low traffic flow.	Near Future	Ontario	Yes	See chapter 8 section 8.4.2.3.2 *Poor Transportation and On-site Storage*
The construction industry should be educated about the different source separation programs that exist.	Near Future	Ontario	Yes	See chapter 8 section 8.4.2.3.3 *Source Separation*
Before any source separation program is selected, consideration should be given about the project type and what the local conditions of the area are.	Near Future	Ontario	Yes	See chapter 8 section 8.4.2.3.3 *Source Separation*
Enough resources, time, and energy should be spent in developing source separation program(s) that will work best for wallboard waste in Southern Ontario.	Future	Ontario	Yes	See chapter 8 section 8.4.2.3.3 *Source Separation*
The construction industry should be educated about the importance of not cross contaminating designated waste bins.	Near Future	Ontario	Yes	See chapter 8 section 8.4.2.3.3 *Source Separation*
The construction industry should first donate and/or reuse any clean wallboard sheets and/or scraps (as long as scraps are at least half the size of the original panel) before they are sent for recycling.	Immediate	Ontario	No	See chapter 8 sections 8.4.2.3.3 *Source Separation* and 8.4.2.3.4 *Landfill Tipping Fees*
Transfer stations and landfills should have designated wallboard waste bins on-site (one source separation program stakeholders can use if they do not want to	Future	Ontario	Yes	See chapter 8 section 8.4.2.3.4 *Landfill Tipping Fees*

create their own).				
Tipping fees should double in order to deter the construction industry from discarding its waste in landfills. With such a significant economic disincentive in place, it will force this industry to eliminate wasteful practices and/or implement source separation programs.	Future	Southern Ontario	Yes	See chapter 8 section 8.4.2.3.4 *Landfill Tipping Fees*
Partnerships and financial agreements should be made between construction companies, wallboard suppliers, and recyclers. These partnerships should involve wallboard manufacturers accepting to use reprocessed gypsum minerals in new wallboard, wallboard recyclers decreasing tipping fees to encourage wallboard recycling, and construction companies willing to discard uncontaminated wallboard waste loads (combination of clean and contaminated wallboard scraps) at recycling facilities for this decreased disposal fee.	Future	Southern Ontario	No	See chapter 8 section 8.4.2.3.4 *Landfill Tipping Fees*
A directory of construction recyclers in Ontario should be created and be easily accessible to all stakeholders.	Near Future	Ontario	Yes	See chapter 8 section 8.4.2.3.4 *Landfill Tipping Fees*
Product Specific Recommendations				
Wallboard manufacturers should use a greater percentage of recycled gypsum wallboard minerals and recycled paper in the manufacture of new wallboard	Future	Southern Ontario	No	See chapter 8 section 8.4.3.1.1 *Product Redesign*
More materials (resistant properties, gypsum) should be added to all wallboard panels to make these panels stronger and more resistant to the outside elements.	Far Future	Ontario	No	See chapter 8 section 8.4.3.1.1 *Product Redesign*
Better fastening methods should be employed (tongue and groove and/or reversible) when installing wallboard to limit the use of tape, nails, and/or screws	Far Future	Ontario	No	See chapter 8 section 8.4.3.1.1 *Product Redesign*

and increase the probability of being dissembled in the future.				
More educational resources should be directed towards the construction industry, especially when it comes to waste reduction strategies, wallboard reuse and donation programs, better ordering techniques, proper handling/installation practices, and environmentally appropriate disposal methods.	Near Future	Ontario	Yes	See chapter 8 section 8.4.3.1.2 section *Educational Programs*
Waste processors should educate wallboard users about the recyclability of wallboard, where recycling facilities exist, and what sellable material these recovered minerals can be turned into.	Near Future	Ontario	No	See chapter 8 section 8.4.3.1.2 section *Educational Programs*
More responsibility should be placed on manufacturers regarding the use and disposal of their product.	Far Future	Ontario	No	See chapter 8 section 8.4.3.1.4 *Extended Producer Responsibility and Full Cost Pricing*
The price of wallboard should increase to represent its true cost by increasing the tax on this material.	Near Future	Ontario	No	See chapter 8 section 8.4.3.1.4 *Extended Producer Responsibility and Full Cost Pricing*
The 3R's regulations should be modified to eliminate any loopholes that exist.	Future	Ontario	Yes	See chapter 8 section 8.4.3.1.5 *Stricter Regulation and Better Enforcement*
The MOE should better enforce the regulations that are already established.	Future	Ontario	Yes	See chapter 8 section 8.4.3.1.5 *Stricter Regulation and Better Enforcement*
A universal waste regulation should be instituted with regards to the construction industry's waste disposal practices.	Far Future	Ontario	Yes	See chapter 8 section 8.4.3.1.5 *Stricter Regulation and Better Enforcement*
A special call line should be created so municipalities and watchdog groups can report poor construction waste disposal practices to the MOE.	Future	Ontario	Yes	See chapter 8 section 8.4.3.1.5 *Stricter Regulation and Better Enforcement*

Municipal landfills in Southern Ontario should work together to create a landfill ban on wallboard waste. Before this ban can be implemented, alternative disposal options need to be well established and the construction industry needs to be educated on these alternatives.	Far Future	Southern Ontario	No	See chapter 8 section 8.4.3.1.5 *Stricter Regulation and Better Enforcement*
Travel distance (under 230 kilometers) should be considered when determining the disposal route for wallboard.	Near Future	Southern Ontario	Yes	See chapter 8 section 8.4.3.1.5 *Stricter Regulation and Better Enforcement*
Laws should be established to prohibit construction waste from being transported to the United States for disposal.	Far Future	Ontario	Yes	See chapter 8 section 8.4.3.1.5 *Stricter Regulation and Better Enforcement*
Better communication should exist between the provincial government and the municipalities.	Future	Ontario	Yes	See chapter 8 section 8.4.3.1.5 *Stricter Regulation and Better Enforcement*
The provincial government should encourage and provide incentives to recycling companies within Ontario.	Future	Ontario	Yes	See chapter 8 section 8.4.3.1.5 *Stricter Regulation and Better Enforcement*

9.2 Recommendations Applicability to Ontario

Although this thesis and the recommendations offered were originally for Southern Ontario, it became apparent that many of these recommendations can also be implemented throughout Ontario. Because this thesis focused on managing wallboard waste in a more sustainable manner, many of the recommendations centered on either improving stakeholder education or implementing better waste minimization behaviors when it comes to wallboard use. After assessing each recommendation (see table 9.1), it was determined that 41 out of the 46 recommendations suggested could be used in any part of Ontario. Most of these recommendations were about changing individuals' behaviors and attitudes and not about building special facilities and/or technologies.

9.3 Contributions

9.3.1 Practical

The practical contribution this thesis provided was a set of feasible recommendations to manage gypsum wallboard waste in Southern Ontario (see table 9.1). The recommendations offered focused both on alternative wall materials as well as changes in practices. The development of these options was based on the waste management hierarchy of refuse (replace), reduce, reuse, and recycle.

9.3.2 Academic

Limited literature exists that amalgamates the concepts of sustainability with the integrated waste management (IWM) approach. For detailed discussion regarding sustainable and IWM see Chapter 3 *Conceptual Framework and Criteria Creation*. This research integrated sustainability concepts with IWM, to evaluate the sustainability of different wallboard management options. It provided the academic field with a comprehensive set of criteria for assessing the feasibility of such options. Another contribution is the ability to use the sustainable IWM criteria set as an evaluation tool in other parts of the waste management field. However, it should be noted that adjustments may need to be made in order for this criteria set to successfully evaluate recommended waste management options.

A further contribution was summarizing the gypsum wallboard literature. Most information regarding wallboard is widely dispersed in journal articles, interior design books/catalogues, and manufacturing websites. The information collected from these various sources is combined here to create an in-depth resource.

9.3.3 Theoretical

The concepts utilized in this thesis included IWM as well as Gibson's and other principles of sustainability. Since the goal of this research was to minimize the adverse impacts connected with wallboard management, a comprehensive set of reasonable options for wallboard waste (refuse (replace), reduce, reuse, and recycle) was developed and evaluated using sustainable IWM criteria. This research was able to add additional knowledge and insight into sustainability and IWM concepts. Furthermore, it was able to draw links between these two concepts.

9.4 Limitations

Few academic resources discuss wallboard waste and/or its management. Extensive searches revealed only a handful of journal articles. The limited scholarly resources that existed made it difficult to find trustworthy information. A further limitation was the number of individuals who could be interviewed and who were willing to be interviewed. Because this research topic is narrow in scope, few experts are available. The number of individuals classified as experts in wallboard management is limited. This research relied on interviews from individuals who had a familiarity with waste management issues or an understanding of construction waste. The small number of individuals who agreed to be interviewed was a further limitation. Individuals who worked in the construction industry were particularly hesitant to participate because of liability concerns, conflicts with company policy, and/or concern that a loss of income would result because of the time it would take to have the interview. Another barrier was the lack of data on the amount of wallboard waste that is actually discarded in Southern Ontario landfills. Data that exist are over a decade old and the numbers given are only approximations. No figures exist that break down wallboard waste disposal by municipality. Because of this lack of data this research was unable to execute any statistical analysis on such matters as wallboard waste trends for Southern Ontario or what the potential diversion rates could be if new management approaches were employed. A further limitation was difficulty in acquiring lifecycle information of certain materials or for that matter what the composition of a product is. The only sources that offered any information were coalition groups, which required membership and a substantial fee. Consequently, there was limited public information about a product's composition or its environmental impacts. A final limitation was the number of generalizations made on the lifecycle of each product. All of these limitations have influenced this thesis' results.

9.5 Future Research

Reflecting back on this topic reveals several areas where future research should head. Areas deserving further research include:

- A more detailed lifecycle analysis on gypsum wallboard.
- Investigation of the environmental impacts associated with gypsum mineral transportation and product development.
- Exploration of the impacts chemically injected wallboard has not only on the environment, but also on recycling.
- Creation of strategies regarding the implementation of the recommended options offered in this thesis.
- Examination of feasible management options available for wallboard waste in areas, such as Northern Ontario, that generate relatively little waste and are far from recycling facilities.
- Examination of feasible management options available to deal with wallboard waste on a smaller scale (e.g. do it yourself projects).

9.6 Conclusion

Although this thesis presented a number of recommendations, there are three fundamental changes that will play the biggest role in getting gypsum wallboard waste to be managed in a more sustainable manner in the future. The first recommendation that needs to be implemented is more resources and educational programs devoted to the construction industry. The research has shown that many individuals in this industry are improperly installing wallboard, are unaware about proper waste minimization behaviors, and are ignorant of the fact that wallboard can be recycled and that wallboard recyclers exist in Southern Ontario. If workers in this industry were given the opportunity to attend educational classes that focused on the proper installation techniques, the use of waste reduction strategies, and the importance of reusing and recycling wallboard waste, not only would there be a dramatic decrease in the amount of wallboard waste produced, but this waste could then be diverted into more environmentally appropriate disposal streams.

The second recommendation that needs to be immediately employed is stricter regulations and better enforcement of the 3R regulations by the MOE. Although the construction industry feels they are overregulated, discussion with waste processors, a review of the literature, and observations at a landfill site as well as at two wallboard recycling plants, have shown that this is not the case. Not only is the amount and type of wallboard waste entering these facilities enormous, but in some cases this wallboard waste is coming from project sites which are not abiding by the 3R regulations. What this information illustrates is that some parts of the construction industry are not taking the 3R regulations seriously. Therefore, it is essential that the MOE devote enough time, resources and manpower to enforce these regulations so that wallboard waste will be better managed in the future.

The last recommendation that should be implemented is increasing landfill tipping fees to force this industry to adopt better waste reduction strategies and divert wallboard waste either to donation centers for reuse or to recycling facilities. Dramatically increasing the tipping fees at landfill sites it will force this industry to change its practices if they want to make a profit. Currently, because landfill tipping fees are similar in price to the recycling center tipping fees, there is no need to change practices. However, if the construction industry were to experience a significant hike in the landfill disposal fee price, it would encourage this industry to adopt better management and disposal practices. The researcher believes that if these three recommendations were implemented, wallboard waste would be managed in a more sustainable manner in the future.

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Appendices

Appendix A: Designer and Architect Questions

1. Is gypsum wallboard the best interior wall product to use?

2. If yes, what makes this material so good?

3. Can you think of any alternative wall materials that could replace gypsum wallboard?

4. What problems will arise if gypsum wallboard is substituted with composite paneling (Medium Density Fiberboard, Oriented Strand board, and Particleboard)

5. Is substituting wallboard with composite panel a feasible wall option?

6. Would this have any effect on employment?

7. How much would use of composite panels affect construction costs?

8. Which material, composite panel or wallboard, is easiest to install?

9. Are most buildings designed to use standard size wallboard sheets?

10. If wallboard was redesigned for easy disassembly, do you believe wallboard disassembly would happen in the future?

11. What factors influence the wallboard product you choose to use?

12. With custom designed projects is there more or less wallboard waste produced?

13. Are wallboard hangers given enough notice when there are changes made to the design of a project?

14. With a residential development project, are houses sold based on a set of generic architectural blueprints?

15. Does the general contractor have the power to make changes to the design of a project?

16. Do you know of any people I could contact who is knowledgeable when it comes to this subject?

Appendix B: Waste Management Coordinator Questions

Bold = Questions only asked to New West Gypsum and Try Recycling

Background information

1. At your facility, what disposal practices are employed for uncontaminated gypsum wallboard waste?

2. At your facility, what disposal practices are employed for contaminated gypsum wallboard waste?

3. What do you believe are the main environmental impacts with landfilling wallboard waste?

4. What behaviors in the past have shown the greatest success in improving other problematic construction waste?

5. **What quantity of wallboard waste is needed to make wallboard recycling feasible at your plant?**

6. **Have you ever thought about establishing more wallboard recycling plants in other parts of Southern Ontario, if so where?**

7. **What is the average distance wallboard waste travels?**

8. **What is the furthest distance wallboard waste has traveled on a regular basis?**

9. How much is your disposal fee?

Validating Recommended Options

1. What disposal problems could arise if wallboard sheets were replaced with composite paneling (Medium Density Fiberboard, Oriented Strand board, and Particleboard)?

2. Which material, composite panel or wallboard, is easiest to manage when clean, and why?

3. Which material, composite panel or wallboard, is easiest to manage when contaminated, and why?

4. Do your find that a lot of wallboard waste entering your facility is clean? If so, what actions are causing so much clean wallboard to be discarded?

5. **Which is more expensive to process contaminated or clean wallboard waste?**

6. If source separation programs for construction waste were employed at the construction site, would this lead to better or worse wallboard management?

7. Do you believe better site control would increase or decrease the amount of wallboard waste generated on project sites?

8. Are you aware of any wallboard recycling facilities in Southern Ontario?

9. In your opinion, are there enough recycling facilities in Southern Ontario to make wallboard recycling a feasible waste management option for the population of Southern Ontario?

10. Do you believe that the construction industry is educated regarding the management of wallboard on the construction site?

11. Do you think the construction industry is educated on wallboard disposal options other than landfilling?

12. What are the best ways to get contractors to produce less wallboard waste?

13. Do you know of any people I could contact who are knowledgeable when it comes to this subject?

Appendix C: Wallboard Hanger Questions

1. On project sites, is drywall waste separated or mixed prior to disposal?

2. Who is responsible for the disposal of wallboard waste?

3. How is clean wallboard waste disposed of?

4. How is contaminated wallboard waste disposed of?

5. What factors influence the disposal decision you employ?

6. What percentage of wallboard waste discarded is clean?

7. Do you transport large wallboard scraps that are clean to your next project?

8. Do you donate large wallboard scraps that are clean?

9. On project sites, is wallboard exposed to the weather elements after delivery?

10. What are the environmental impacts connected with landfilling wallboard waste?

Validating Recommended Options

1. What problems will arise if gypsum wallboard is substituted with composite paneling (Medium Density Fiberboard, Oriented Strand board, and Particleboard)

2. Is substituting wallboard with composite panel a feasible wall option?

3. Which material, composite panel or wallboard, is easiest to install?

4. What on-site behaviors lead to the creation of unnecessary wallboard waste?

5. Are most buildings designed to use standard size wallboard sheets?

6. If wallboard was redesigned for easy disassembly, do you believe wallboard disassembly would happen in the future?

7. What factors influence the wallboard product you choose to use?

8. Do you find that some wallboard waste created is due to changes made to the design of a project in which there was insufficient notice?

9. Do you have up-to-date product inventory lists?

10. Do you find that some wallboard waste created is due to ordering errors?

11. Do transportation practices ever lead to the on-site delivery of damage wallboard?

12. Does wallboard sometimes get damage during its storage on-site?

13. Do you know of any wallboard recycling plants in Southern Ontario?
    If No, skip to question 15 if yes ask next question

14. Do you use this facility? If yes why? If no, why not?

15. Does the construction industry need additional education on proper wallboard management practices?
    If No, skip to question 17, if yes ask next question

16. What aspect (practices, disposal techniques, etc…) needs more education?

17. Would a just-in-time delivery approach change wallboard waste totals?

18. What are the best ways to get contractors to produce less waste?

19. Do you know of any people I could contact who is knowledgeable when it comes to this subject?

Appendix D: General Contractor Interview Questions

1. On project sites, is construction waste separated or mixed prior to disposal?

2. Who is responsible for the disposal of construction waste?

3. How is clean wallboard waste disposed of by your company?

4. How is contaminated wallboard waste disposed of by your company?

5. What factors influence the disposal decision you employ?

6. What percentage of wallboard waste discarded is clean?

7. Do you transport large wallboard scraps that are clean to your next project?

8. Do you donate large wallboard scraps that are clean?

9. On project sites, is wallboard exposed to the weather elements after delivery?

10. What are the environmental impacts connected with landfilling wallboard waste?

11. What behaviors in the past have shown the greatest success in improving other problematic construction waste?

Validating Recommended Options

1. What problems will arise if gypsum wallboard is substituted with composite paneling (Medium Density Fiberboard, Oriented Strand board, and Particleboard)

2. Is substituting wallboard with composite panel a feasible wall option?

3. Would this have any effect on employment?

4. Which material, composite panel or wallboard, is easiest to install?

5. What on-site behaviors lead to the creation of unnecessary wallboard waste?

6. Are most buildings designed to use standard size wallboard sheets?

7. If wallboard was redesigned for easy disassembly, do you believe wallboard disassembly would happen in the future?

8. What factors influence the wallboard product you choose to use?

9. Do you find that some wallboard waste created is due to changes made to the design of a project in which there was insufficient notice?

10. Do you have up-to-date company product inventory lists?

11. Do you think it is important to have a clause in your trade workers' contracts that make them responsible for any wasteful practices they may employ?

12. Do you find that some wallboard waste created is due to ordering errors?

13. Do transportation practices ever lead to the on-site delivery of damage wallboard?

14. Does wallboard sometimes get damage during its storage on-site?

15. Do you believe landfill disposal fees will increase or decrease if waste reduction initiatives are implemented?

16. How much would landfill tipping fees have to increase before the construction industry would change its practices with regards to wallboard waste?

17. Do you know of any wallboard recycling plants in Southern Ontario?

    If No, skip to question 19 if yes ask next question

18. Do you use this facility? If yes why? If no, why not?

19. Does the construction industry need additional education on proper wallboard management practices?

If No, skip to question 21, if yes ask next question

20. What aspect (practices, disposal techniques, etc…) needs more education?

21. Would a just-in-time delivery approach change wallboard waste totals?

22. What are the best ways to get contractors to produce less waste?

23. Do you know of any people I could contact who is knowledgeable when it comes to this subject?

Appendix E: Results from Guided Observations

Region of Waterloo

Day and Time

On Monday March 2, 2009 an observation session was conducted at the Region of Waterloo landfill site, which is located at 925 Erb Street West in the City of Waterloo. It is 126 hectors area of which 71 hectors is dedicated to the disposal of residential and commercial waste. The session began at 11:15 and ended at approximately 11:45am.

Site Layout

During the session, a facility vehicle was used to tour the site. Due to liability and safety concerns an employee was present throughout the tour and observation session. The researcher was able to witness first-hand the disposal actions that take place on-site. When waste is brought to this facility, the load must be weighted at the main scale before it can proceed to the active tipping area. A spotter is stationed on the main road directing the truck to the appropriate unloading area. Once the truck is unloaded, it is reweighed to determine the tipping fee. Currently, the fee is $64 per tonne, but will increase to $68 per tonne on July 1, 2009. After the load is dropped off, heavy duty machinery such as bulldozers and compactors are used to compress the waste material. Waste loads that are cleared for landfill disposal are all unloaded in the same tipping area. Although donation trailers (Goodwill and Habitat for Humanity) exist on-site, it is up to the waste hauler to drop off any materials that can be reused. During the tour, the guide explained that each night, the active tipping face is covered with either spray-on foam or a tarp, to reduce odor and prevent litter dispersion.

Observation

There is no designated area for construction waste. The tour guide explained that wallboard waste can be landfilled because there are no bans in place preventing this disposal option. The guide did inform the researcher that there was a pilot project in the works with New West Gypsum (NWG) involving the diversion of wallboard waste away from the

Waterloo landfill. It was difficult to estimate the amount of gypsum wallboard entering the facility since it was always mixed with other construction waste. However, the guide did explain that a substantial amount of gypsum wallboard is discarded in this landfill each year. In terms of wood waste, only clean wood can be diverted away from the landfill. Composite paneling and other wood products must be landfilled. This waste is not recycled due to concerns regarding the chemical adhesives used to protect wood products. Because construction waste is landfilled and there are no diversion programs in place, one observation session was adequate.

Sittler Environment Incorporated

Date and Time

On Wednesday March 25, 2009 an observation session was carried out at the Sittler Environmental Incorporated business. This company specializes in the management and disposal of construction, renovation and demolition (CRD) waste. Because this company collects and handles all types of construction waste from the local area, it operates two facilities. The first facility is on a 2 acre lot located at 36 Centennial Road in Kitchener, Ontario. The second facility is on a 40 acre lot located on the outskirts of Elmira at 2660 Arthur Street. An observation session at the Kitchener facility began at approximately 10:05 and ended thirty minutes later at 10:35. This facility was selected over the Elmira location because most of the waste sent to Sittler's is first brought to the Kitchener site. Once at this facility the waste is separate and depending on the waste composition will influence whether it is hauled to the Elmira facility.

Site Layout

The site is designed with a circular traffic pattern. Trucks that enter the facility are first stopped and weighed at the main scale. Depending on the composition of the load or whether the load is mixed or separated, will influence which unloading zone the truck is directed to. Different waste disposal stations on-site include: wood, masonry, metal, gypsum, shingles, and regular garbage waste (see pictures below). Once the waste is unloaded, the truck exits the facility where it is reweighed to determine the amount of waste discarded. Currently the tipping charge is $64 per tonne for a mixed load of construction and demolition (C&D) waste. This fee does fluctuate depending on the client, cleanliness of the load, and the type of waste brought to the facility. Disposal fees are lower for good customers as well as for construction waste that is in high demand in this case wood pallets and certain types of metals. Due to liability and safety concerns, a Sittler's employee was present throughout the entire tour and observation session. Even though an employee accompanied the researcher, it did not have a significant impact since the researcher was still able to witness firsthand how this site operates.

Observation

Throughout the thirty minute observation session there was always a constant flow of truck traffic entering and leaving the facility. The trucks were a combination of Sittler owned waste hauling trucks in addition to third party waste disposal trucks that came from such companies as Waste Management. In addition to the large transport trucks, there were also a few smaller pickup trucks. Most delivery loads were mixed. The only loads that were not mixed came from sub trades who were dealing with only one type of waste. In instances like this, the sub trades unloaded the waste into the appropriate disposal station. Loads that were mixed were unloaded in the mixed waste section, which was located at the back of the facility in an enclosed building. Once the material was unloaded onto the main floor various machines including: bulldozers and diggers separated the mixed waste into different piles. There were also hand sorters on the floor and at the different disposal stations. The job of these employees was to ensure no contamination from other waste materials. Once there was enough waste at the disposal station, the waste was then loaded into Sittler tractor trailers. These trucks transported the waste either to the Elmira facility or to another processing facility for recycling. Construction materials transferred to the Elmira for processing included clean and contaminated gypsum, wood waste, masonry, and shingles. In terms of the metal waste, it is hauled off to a recycling plant where it is reprocessed into new material. Construction waste that cannot be process by Sittler's is sent to local landfills for final disposal.

New West Gypsum

Date and Time

On Wednesday April 8, 2009 a facility tour and observation session was carried out at New West Gypsum (NWG) located in Oakville, Ontario at 2182 Wyecroft Road. As the name indicates, this company focuses on the recycling of both clean and contaminated wallboard waste. This session began at 9:50 and lasted approximately thirty minutes. Once again, due to liability issues, an employee shadowed the researcher throughout the observation session for safety reasons. It should be noted that this employee did provide useful insight about what takes place at this facility.

Site layout

When trucks enter the facility, they drive onto the main scale where they are weighed. Once weighed, they are given clearance by the scale operator to proceed to the warehouse to discard their waste. At the warehouse entrance, a huge automatic door is opened and the truck enters. After the truck waste is unloaded by the forklifts, it leaves the warehouse and travels back to the main scale where it is reweighed to determine the amount of wallboard waste that was discarded.

Observation

During the observations session, two vehicles were at the site – one was a flatbed transport truck and one was a pickup truck. The waste from the transport truck was full size wallboard panels that were clean. This truck had come from one of the three wallboard manufacturing plants located on the outskirts of Toronto. These panels were brought to the facility because they did not meet company standards. The employee explained that they are the only facility in Ontario that is able to manufacture drywall panels that come from the manufacturer still wet. Although other wallboard recyclers exist, they are unable to handle new wallboard that has not gone through the drying process. On average 50 tonnes of new wallboard sheets are discarded daily by these manufacturers, which equates to 5% of their daily manufacturing total while 80 tonnes is disposed by the construction industry and private/public landfills. The other vehicle observed was a local drywaller who came to the facility to discard his wallboard waste scraps. The transport truck that was at the facility drove into the warehouse and drove onto the plant's tipping floor. Once the waste is brought in, several workers surround the truck and began to take the wallboard sheets off with forklifts. The forklifts transport these sheets to the back of the warehouse where they are loaded onto a large feed hopper. The employee explained that when wallboard comes from construction site and/or landfills this waste is first emptied out on the tipping floor before it can go into the hopper. He explained that it has to be emptied out to ensure there is no cross contamination of other waste like wood, plastics, garbage, and so forth. Once through the hopper the wallboard is transported by conveyor belt through various magnetic zones. These magnetic fields are strong enough to pickup any ferrous metal that may exist in the passing product. Once through the magnetic separator area, it is transported by conveyor to the processing unit where the paper is separated from the gypsum board. Due to safety reasons, the researcher was unable to see how this processing unit worked. The paper taken off the panels is collected and trucked to a nearby farmer where it is used for animal bedding. The powder gypsum that remains is stored at the other end of the warehouse where it waits to be transported back to Certainteed. This company, on average processes 100 to 150 tonnes of drywall a day. It should be noted that this warehouse was filled with gypsum dust. Everywhere the researcher went, the floor, walls, and ceiling were covered with a thick layer of gypsum. Although many of the employees had protective masks around their neck, none of them were using them.

Appendix F: Results from Semi-structured Interviews: Architect and Architectural Designer

Background

Two architects and one architectural designer were interviewed. These interviews were conducted in a semi-structure manner. A set of generic questions were used to have some question consistency (see appendix A). The purpose of these interviews was threefold: 1) to learn about the procedures involved in building design and material selection; 2) to understand the legal requirements that architects must abide by when designing a structure; and 3) to determine the feasibility and practicality of replacing wallboard with alternative wall materials. After the third interview, it was decided no more architectural based interviews were needed, due to response consistency and the lack of new information being put forward.

Dates, Times, and Business Backgrounds

The first interview was conducted with Lou Gere an architectural designer who worked for the Activa Group. This group is a land developing company that specializes in turning vacant land into livable communities. Last year this group expanded their operations to include a general contracting company. This company currently manages both commercial and residential projects. This interview was held on March 20, 2009 at approximately 9:00 am at the Activa headquarters located in Waterloo, Ontario. It lasted roughly thirty-five minutes. During this interview, the names of two additional architects were recommended. Both of these architects were contacted as well and both agreed to be interviewed. The second interview was conducted with Jim Fryett of James Fryett Architect Inc. This interview was held on March 23, 2009 in Elora, Ontario at the James Fryett Architect Inc. building. It began at 1:00 pm and concluded half an hour later at 1:30pm. This company is a medium size architect firm that specializes in the design of commercial, industrial, and residential projects. The last interview was with a SRM Architects Inc. employee who wished to be anonymously identified. This interview was also held on March 23, 2009. Although this firm is located in Waterloo, Ontario, a telephone interview was carried out based on the request of the interviewee. It started at 2:40 and ended approximately fifteen minutes later. This architect firm is also considered a mid-size business, which also focuses on the design and development of commercial, institutional, and multi-residential projects.

Response Organization

Responses to the interview questions were group under the categories of similarities and differences. These two categories were selected because the responses received from each question were either alike or dissimilar.

Similarities

Each interview began with a discussion about wallboard and whether it is the best interior wall product to use. All interviewees agreed that it is an excellent wall material, but were hesitant to say whether it was the best. The inexpensive purchasing price of wallboard and the extreme versatility of the material were the reasons cited. When asked whether any alternative wall materials could replace gypsum, Jim Fryett and the SRM Architect employee both indicated some type of wood product. Mr. Fryett went on to explain that using a wood type wall material would only work under certain circumstances. He explained that having a good understanding of building code regulations and coming up with unique solutions that would not only satisfy the building code inspectors, but also comply with other safety standards would be the only way that alternative wall materials could replace wallboard.

When asked whether most buildings are designed to use standard wallboard sheets, there was again agreement. Buildings are not designed to use standard size wallboard sheets, but rather the reverse is true wallboard sheets are created to fit a variety of buildings. The variety of wallboard dimensions available today is done by wallboard manufacturers to accommodate a multitude of building designs (SRM Employee, 2009). In the case of residential projects, home design is typically based on pre-cut wood studs that are a height of eight feet one inch. When drywall is installed, two pieces of four foot drywall are combined together to form an eight foot piece. One inch of clearance is left over. This inch is split between the floor and ceiling to deal with any irregularities that may exist (Gere, 2009; Fryett, 2009). In the case of commercial, industrial, and institutional buildings, design is driven by masonry modules. Because masonry materials are difficult to cut, architects design buildings, in which the least amount of masonry cutting is needed. The fact that wallboard is so easy to cut results in wallboard not given any consideration in the design of any structure (Gere, 2009; Fryett, 2009).

With custom designed projects, both architects agreed that there is added wallboard waste. They explained that even with good drywall hangers who are creative in the installation techniques they use, excess waste is still produced. This waste is usually created in the form of off-cuts, in which extra wallboard sheets are used to extend wall heights or to make custom design ceilings.

Cost and abiding by building code regulations are the main factors that influence the wallboard product designers and architects choose to use. These interviewees explained how there are laws in place to self govern what wallboard grades can be suggested in the first place. In circumstances where walls have to have a high fire rating, the wallboard choices available are quite limited. Aside from meeting building code regulations and cost, satisfying the client's wants while suggesting a wallboard material that is a good performer and aesthetically pleasing are further factors designers and architects consider when selecting wallboard (Gere, 2009; SRM Employee, 2009).

If wallboard was redesigned for easy disassembly, would disassembly happen in the future was another question asked by the interviewer. A sense of no was the common response received. The different explanations given included: the breakability of wallboard reduces its chance of staying intact when it is disassembled and moved for reassembly; the walls may have been abused and contaminated with paint or decorative overlays that will not work if moved to another area; the chance of these walls being dissembled in the future is rare; and finally the premium cost associated with their installation.

In terms of whether composite paneling could ever substitute wallboard in the future, all agreed it was possible, however there were varying degrees of confidence. With the SRM employee, he had three concerns. First, is there enough wood waste or harvested wood to produce composite panels at a volume that gypsum wallboard is currently being consumed at; second, would building code regulations allow this product to be used; and third, what would be the extra cost incurred from using this material . Because of these concerns, he thought that composite paneling could only be used for residential houses and smaller buildings where building code regulations are less stringent and the use of combustible materials is allowed. In terms of larger buildings, this wall material would not be a practical solution because of the extra costs associated with treating the wood to make it noncombustible. On the other hand, Mr. Fryett was confident that composite panels could be used as an alternative wall material in the future. The only comment he did mention involved making sure that certain steps could be taken, whether injecting chemical resins into the panels to make them noncombustible or adding additional safety equipment like sprinkling systems, which would meet and satisfy building code standards. In term of Mr. Gere, his level of confidence was somewhere between these two individuals.

In deciding whether composite paneling is a feasible wallboard replacement option, questions regarding the impact it will have on construction costs and installation ease were immediately asked. In terms of composite panel's effect on construction costs, all three individuals agreed that an increase cost would transpire. While wallboard is a naturally fire retardant material, composite panel is a naturally combustible material and this is where the problem lies. Injecting various fire retardants into composite panels will increase material costs. The use of combustible versus noncombustible panels depends on the structure being constructed. In instances where a project allows the use of combustible materials, like composite panels, construction costs will be similar to projects in which wallboard sheets are used.

When it comes to installation ease, two out of the three felt that wallboard is the easiest to install while Mr. Fryett believed that the installation ease between wallboard and composite panels would be the same. The question then becomes, which material is easiest to finish. Mr. Fryett explained that both products are difficult to finish, but in very different ways. In the case of drywall, the sanding of the panels results in the release of wallboard dust. This dust is a concern because of the impact it can have on human health. With composite paneling, more paint is required to get a nicer finish because of its graininess. In examining both of these products there are advantages and disadvantages with using either one. With wallboard, even though it is slightly easier to install, finishing is harder and the chance of breakage is higher. In the case of composite panels, although they are somewhat harder to install, finishing tends to be easier and the chances of them being damaged is lower.

Differences

When asked what problems arise if gypsum wallboard is substituted with composite paneling, a diverse set of responses were obtained. With Mr. Gere, the only concern he raised involved installation ease. He explained that wallboard is extremely easy to install and highly forgiving. With other materials like composite panels, the question becomes how hard will it be to install and finish. The SRM employee brought up the issue of stretching the renewability of wood to meet gypsum wallboard volumes. This interviewee was concerned that there will not be enough wood waste and harvested wood to meet consumption levels that gypsum wallboard can meet. With Mr. Fryett, his apprehension focused on satisfying Ontario Building Code (OBC) requirements and the combustibility of composite panels. He explained that if composite panels replaced wallboard, the problem would be illustrating to building code officials that this replacement option is safe. Because these panels are identified as combustible, was his second concern. When materials are identified as combustible, not only is there more hesitation by the public, but building code conditions become more stringent. He explained that these codes become more inflexible because these codes are trying to protect the life and safety of individuals that are inside the structure. Therefore, if combustible material is being used, more pressure is placed in ensuring this material is suitable to use. The extra steps needed to be taken to prove that composite panel can be a suitable wall option was a major concern raised by Mr. Fryett.

The project type is what dictates who has the power to make design changes on a project. Mr. Fryett and the SRM employee both explained when changes are made during the development of single family home the designer has the power to approve these changes. In Ontario, home builders that are registered under Tarion, a warranting insurance company, are permitted to make changes and redesign residential project. With industrial, commercial, and institutional projects, this approval process is different. If changes are made to these projects, architectural approval must be granted. In the case of Mr. Gere, he explained that no matter the project type, any design changes must go through an architect.

Unique Points Raised

Throughout the interview some interesting side comments were made. These included:

- Building regulations are influenced by the size and height of a structure. The bigger the size and the greater the height of the structure, the more stringent the requirements are (Fryett, 2009).
- It is important to have clauses in trade worker's contract that make them accountable for wasteful practices (Gere, 2009)
- There has to be more education on proper wallboard management techniques. This education needs to focus throughout the lifecycle of a product- from manufacturing procedures, to installation practices, to handling and disposal processes (Gere,2009)
- To get contractors to produce less waste, there needs to be higher disposal fees. The higher the cost, the more likely this industry will implement waste reduction initiative and adopt better disposal techniques. Furthermore, a whole industry approach needs to be taken when adopting these solutions or it will not work (Gere, 2009).

Appendix G: Results from Semi-structured Interviews: Waste Management Coordinators

Background

Four waste management coordinators were interviewed. These interviews were once again conducted in a semi-structure manner using a set of different generic questions (see appendix B). One question was eliminated halfway through the interview process because of confusion. Although the question was re-explained in a different way, the responses obtained still indicated confusion and therefore it was eliminate for the third interview. The purpose of these interviews was threefold: 1) to learn about composition of wallboard waste entering these facilities; 2) to ascertain the waste management procedures employed to deal with wallboard waste; and 3) to determine the disposal problems that could arise if wallboard was replaced with composite panels. The unique discussion each of these individuals offered helped the researcher acquire an adequate representation of the different wallboard disposal options available. After the fourth interview, it was determined that enough information was obtained and that no more interviews with waste management individuals were needed.

Dates, Times, and Business Backgrounds

The first interview was conducted with a New West Gypsum (NWG) Employee who wished not to be identified in this report. This company is a waste disposal facility that specializes in the recycling of clean and contaminated wallboard waste. This interview was conducted by telephone due to the individual being located in Vancouver, British Colombia. It was held on March 20, 2009 at 1:00 pm and last approximately twenty minutes. The second interview was with a Sittler employee whose name will also not be identified due to anonymity reasons. This in-person interview was carried out on March 25, 2009 at Sittler's Environmental Incorporated building, located in Kitchener, Ontario. It began at 9:10 and ended fifty-five minutes later. This company not only caters to the disposal and recycling of construction, renovation, and demolition (CRD) waste, but also provides other services, which include waste audits, demolition, land clearing and grubbing, and site remediation. The third interview was conducted at the Region of Waterloo landfill, with landfill manager

Jon Arsenault. This interview was also held on March 25, 2009. It started at 11:15 and last approximately thirty-five minutes. This facility accepts and landfills all construction waste that is deemed nonhazardous. The last interview was a telephone interview with Mark Waring, a Try Recycling employee. This interview took place on March 26, 2009 it started at 10:00 am and concluded thirty minutes later. Try Recycling is a disposal facility, which is located in London, Ontario. It focuses on the collection and recycling of C&D waste.

Response Organization

Because many of the questions asked were either factual or opinion based, the response received from each interviewee was unique. As a result, questions were organized under different categories, which include: information regarding facility practices; knowledge acquisition and personal opinions; and alternative material consideration (see table 0.1- table 0.3). Arranging the questions based on similarities and differences was impossible because of the diversity in the answers. This approach made the most sense because the researcher could easily highlight key points raised by each interviewee. Response tables have been created to convey this information and are given below. Many of the questions in the question column are in an abbreviated form.

Information Regarding Facility Practices

Depicted in the table below is a summary of responses given to questions which focused on facility operations. It should be noted that some confusion arose between the researcher and interviewee regarding the meaning of clean wallboard and contaminated wallboard. This confusion was resolved once the researcher explained their definition of the two key words.

Table 0.1 Response received by interviewees regarding questions based on facility operations.

Questions	**Interviewees**			
	New West Gypsum Employee	Sittler Employee	Jon Arsenault	Mark Waring
1. Disposal practices for clean wallboard waste	Recycled	Recycled	Landfilled	Recycled
2. Disposal practices for contaminated wallboard waste	Recycled unless contaminated with dirt and/or asbestos	Recycled – unless contaminated with hazardous material	Landfilled	Recycled – unless contaminated with asbestos or other hazardous materials
5. Quantity of wallboard needed to make wallboard recycling feasible	35 to 45 thousand tonnes a year and this volume is received by NWG each year		Not applicable	2 to 3 thousand tonnes a year – wallboard is an on demand product a load will not be process until 100 to 150 tonnes are brought in
6. Establishment of other wallboard recycling facilities	Not in Ontario because this plant is only operating at half capacity. Next facility will be in Montreal because a board manufacturing plant is located there		Not applicable	Closer to Toronto
7. Average distance wallboard waste travels for disposal	40 kilometers – Toronto area	Waterloo Region	Waterloo Region	50 kilometers – immediate London area
8. Furthest distance average wallboard waste travels for disposal	500 kilometers – once a month loads are brought in from Ottawa due to LEED projects			200 kilometers – 20 to 30% of wallboard waste will come from the Golden Horseshoe
9. Tipping fee for discarded wallboard waste	$57.50 per tonne, but rates may change depending on volume and customer	$64.00 per tonne but rates may change depending on volume and customer	$64.00 per tonne and will go up to $68.00 on July 1st	$72.00 per tonnes, but rates may change depending on volume and customer
Under Validating Recommended Options				
4. Percentage of wallboard waste entering the facility that is clean	98% – most wallboard entering the facility comes from new construction projects	Majority	Majority	60% to 70% - some of the wallboard is from demolition and renovation project, but most comes from new construction

5. Differences in processing price depending on the condition	No difference in price	No difference in price	Not applicable	No difference in price

The first set of questions focused on the disposal methods employed for clean and contaminated wallboard waste. Three out of the four interviewees indicated their facilities took part in wallboard recycling as long as the wallboard contained no hazardous materials. They explained that the processing techniques were the same for both clean and contaminated wallboard waste. In terms of how these facilities recycled the waste is where their differences lie. With NWG, the boards are placed on moving belt. This belt passes through a hopper machine and magnetic zone where any metal contaminates are removed. The board is then transported to the processing unit where the paper backing is separated from the gypsum board. This gypsum is processed into a powder form where it is shipped to a nearby wallboard manufacturer (Certainteed Gypsum) where it is remanufacture into new wallboard. In the case of Sittler, the first step involves separating wallboard waste from other construction waste materials. The separated wallboard is then either ground or crushed, depending on what process is implemented. The employee explained that currently two different wallboard recycling techniques are being used. This has been done to determine, which approach provides a better end product. As the wallboard sheets are sent either through the crusher or grinder, they pass through a magnet where any ferrous metal found within the boards are removed. Once the wallboard exits, it is sent to the screening plant where a trommel screen is used to separate the paper from gypsum minerals and any metal that still remains. With Try Recycling, the same grinding process utilized by Sittler is also used by them. The sellable product that recycled wallboard is turned into, is where differences exist between the two companies. Sittler uses the recovered minerals in compost piles and as a soil neutralizer. Try collects the waste paper (both clean and contaminated) and sells it as an industrial absorbal product. This paper is used as a bulking agent when hazardous waste is transported. The recycled gypsum is sold as an agricultural fertilizer to control pH levels of soil.

Knowledge Acquisition and Personal Opinions

The next group of questions focused on how aware and knowledgeable these interviewees were about the wallboard waste situation as well as elicit personal opinions of what they believe needs to happen to improve the management of this waste. Once again, the best way to communicate the responses was in the form of a response table (table 0.2).

Table 0.2 Response received by the interviewees regarding questions that focused on both knowledge acquisition and personal opinions

Questions	**Interviewees**			
	New West Gypsum Employee	Sittler Employee	Jon Arsenault	Mark Waring
3. Environmental impacts with landfilling wallboard	Release of hydrogen sulphide gas and the loss of a resource that could have otherwise been recovered and reused	Not aware of any	The loss of a resource that can be recycled, the release of hydrogen sulphide gas, and is extremely odorous	Losing precious landfill space and the loss of a resource that could be reused again
4. Past behaviors that have shown success in improving other problematic construction waste		Banning the waste from entering landfills and finding alternative uses for the waste that lead to extra income	Diversion programs for waste that can easily be segregated	Cost effective models and government intervention – implementation and enforcement of stricter regulations
Under Validating Recommended Options				
6. Source separation programs and its impact on construction sites		Will lead to better wallboard management		Will open the industry's eyes – the optics of seeing clean wallboard sheets in waste bins may change this industry's perception and push them in a direction of adopting less wasteful behaviors
7. Better site control will increase or decrease wallboard waste generation totals	Decrease – but there needs to be more educational programs in place to train workers on better site control	Decrease – the construction industry is starting to control their sites better because this is one	Decrease – but there needs to be educational programs as well as incentive and/or	Decrease – better site control can be achieved through implementation of: just-in-time delivery system and covering

	techniques	cost they can control	regulation in place for better site control to happen	up materials to protect them against the weather elements
8. Awareness of wallboard recycling facilities in Southern Ontario	None that use the recovered gypsum minerals in the manufacturing of new wallboard	Sittler, New West Gypsum and, Try Recycling	New West Gypsum	New West Gypsum and Try Recycling
9. Are there enough recycling facilities in Southern Ontario for the population of Southern Ontario	Yes since this facility is only operating at half capacity, but no there are not enough transfer station in Southern Ontario that collect this waste and send it for recycling	Yes – but there needs to be more municipalities and transfer station willing to collect this waste and send it for recycling	Yes	It depends on the market and whether there not only is a continual flow of this material, but also a constant demand for the sellable products this recycled waste can be turned into
10.Is the construction industry educated regarding the management of wallboard on construction site		Think they are, but not sure	They have a good understanding, but they are not fully educated	They are getting better, but they have a long way to go – most wallboard waste dropped-off today are off-cuts compared to the entire sheets seen in years past
11. Is the construction industry education regarding wallboard disposal options other than landfilling		Probably 50% of the industry would know of alternative disposal options, especially individuals working on LEED projects	Some individuals are, while others are not. Individuals who are unaware that alternative disposal options exist, are not seeking these options because there is no competitive advantage to do so	No – because individuals in the industry have a false assumption that recycled wallboard waste can only be used in the remanufacturing of new wallboard, which is wrong. This industry is unaware that other recycling companies exist that can turn recovered gypsum into other sellable products
12. What is the best way to get contractors to produce less wallboard waste	Teaching wallboard hangers proper installation techniques in order to eliminate some of their wasteful practices	Buy wallboard sheets that fit closes to the wall height being constructed	More education, reduce tipping fees at recycling centers to make it more cost competitive,	Increase tipping fees for C&D waste at landfills as a way of forcing this industry to divert its waste to recycling facilities, and have regulations in place that restrict

			and regulatory codes that push for waste diversion	wallboard from landfill disposal

When it comes to behaviors in the past, that have shown success in improving other problematic construction waste, Mr. Waring responded with governmental intervention and the cost effectiveness model. He explained that implementing these two actions will improve the management of wallboard. He discussed how the biggest challenge as an industrial recycler is proving to the construction industry that recycling is a cost effective disposal approach. The mentality that landfill disposal fees will always be cheaper then recycling fees is where the problem lies. The construction industry needs to know that it is financially feasible to recycle their waste. The only way to illustrate this point is through the cost effective model. Showing companies the price difference between these two disposal choices will bring awareness to the industry about the misguided belief they follow. Another action in the past that has created change is government intervention through the implementation and enforcement of regulations. Mr. Waring went on to explain that in 1994 the government launched a number of waste reduction regulations (101, 102, and 103) that focused on better handling and disposal of construction waste. Although these regulations were implemented, their success was minuscule due to regulation loopholes and limited enforcement. If the government established new regulations that were more binding and were more strictly enforced, he believes significant improvement in wallboard management would come about.

<u>Alternative Material Consideration</u>

The last group of questions was interested in determining the adverse impacts that could transpire if wallboard was replaced with an alternative material. A response table (table 0.3) was once again employed to illustrate the answers that were obtained.

Table 0.3 Response received by the interviewees involving the impact they would expect if wallboard was replaced with an alternative material.

Questions	**Interviewees**			
	New West Gypsum Employee	Sittler Employee	Jon Arsenault	Mark Waring
Under Validating Recommended Options				
1. Disposal problems that will arise if wallboard is replace with composite panels	More costly	No recycling options for composite panels that are injected with fire retardants	Unaware of what recycling market exists for composite panels	There are no big problems with recycling either of these materials. The one problem that does exist is an inability to recycle composite panels that are injected with fire retardants
2. Which wall material will be easiest to manage when clean	Wallboard because we only specialize in wallboard recycling	Wood as long as the panels are not injected with fire retardants	Wallboard	Wallboard and untreated particleboard
3. Which wall material will be easiest to manage when contaminated	Wallboard because we only specialize in wallboard recycling	Wood as long as the panels are not injected with fire retardants	Wallboard	Wallboard and untreated particleboard

When these waste coordinators were asked about the disposal problems that could arise with the recycling of composite panels, for the most part they were unaware of any big problems. As a result, the focus of this question shifted to a discussion regarding the different products that untreated composite panels can be recycled into. At Sittler's these panels are finely ground up and sold as either landfill cover or as an additive used to thicken up sewage sludge. Before Sittler ground up their wood waste, they used to ship it to Bancroft where these panels along with other wood materials were used in the manufacturing of new panel products. In the case of the Waterloo landfill, composite panels are typically landfilled unless they are mistakenly discarded in the wood pallet area. In instances where these panels are combined with the wood pallets they are chipped up. The reason why Waterloo does not chip composite panels is the chemical adhesives that may have been injected into them and because the demand for this wood waste is not high. At Try, instead of discussing the different wood product wood waste is made into, Mr. Waring instead spoke at length about the lack of awareness regarding wallboard recycling. He explained that contractors have latched on to wood separation and recycling because wood recyclers have educated the construction industry about it. With wallboard, however, wallboard recyclers have failed to educate this industry that wallboard is a recyclable product and that facilities exist throughout Southern Ontario to handle it. He believes that education is an important tool in getting the construction industry to accept wallboard recycling as the best disposal option available.

<u>Unique Points Raised</u>

Throughout the interviews interesting side comments were again made. Some of these comments included:

- New West Gypsum technology allows 20% of new wallboard to be made with the recovered gypsum that is processed at their facility (New West Gypsum Employee, 2009)
- It is estimated that only 25% of wallboard waste is recycled while the remaining 75% is landfilled (New West Gypsum Employee, 2009)
- If transfer stations along with landfills, supplied depots to drop-off wallboard waste, this approach could divert a lot of wallboard waste away from landfills (Sittler Employee, 2009)
- Many individuals within the construction industry are set in their ways. There needs to be incentives or regulations in place for these individuals to change their wasteful behaviors (Sittler Employee, 2009).
- Construction companies, especially now because of the downward spiral of the economic market, are only concerned about their bottom line. If better wallboard disposal behaviors are going to cost them more, they will be less likely to adopt these behaviors because there is nothing stopping them from continuing with these environmentally irresponsible behaviors (Arsenault, 2009).
- Although the 3Rs regulations have been implemented since the early 1990s, companies are not abiding by them because they are not being penalized. We as a

landfill facility cannot enforce them because they are provincial regulations (Arsenault, 2009).

- Region of Waterloo is in the process of starting a wallboard pilot program. The Region is in talks with their primary wallboard generators to see if they are onboard and willing to separate their wallboard waste from regular construction waste. The problem with launching a wallboard diversion program is the risk of wallboard waste being contaminated with other construction waste. This added contamination could lead to an increase in disposal fees because of extra time and manpower needed to separate the materials Arsenault, 2009).
- There are several reasons why Sittler and Try Recycling are typically not identified as wallboard recyclers in the waste management industry. First, most wallboard recyclers used their reclaimed gypsum in the manufacturing of new wallboard which is not the case for Sittler and Try. Second, the volume of gypsum received is minuscule compared to the amount NWG receives. And third, they focus on the recycling of other construction material and not just gypsum (Waring, 2009).

Appendix H: Results from Semi-structured Interview: Trade-worker

Background

One trade worker who specialized in wallboard hanging agreed to be interviewed. This interview was conducted in a semi-structure manner. A prepared set of questions was employed to ensure some question uniformity (see appendix C). The objective of this interview was to: 1) understand how wallboard is managed both on and off project sites; 2) determine what behaviors lead to the creation of unnecessary wallboard waste; and 3) determine whether it is feasible to replace wallboard with another material and what impact this will have on wallboard hangers. Because of the unwillingness by the drywalling community to participate in this research, only one trade worker agreed to be interviewed. The drawback with conducting one interview is the inability to compare it to anything else. When multiple interviews are done, the researcher is able to compare and contrast the differences that may exist between each question. When there is only one interview, the reliability and validity in responses can come into question. Through corroboration with the literature review and discussion with general contractors, this problem was resolved.

Days, Times, and Business Background

This interview was conducted by telephone with a Rosmar Drywall employee who wished not to be identified in this report. The interview was held on March 19, 2009 and began at 2:50 pm and lasted approximately ten minutes. This company is located in Guelph, Ontario and specializes in drywall hanging. The jobs they focus on are commercial, industrial, and institutional projects.

Response Organization

The responses obtained from this individual were typically one word answers. The limited discussion of responses could have been due to many of the questions being focused on obtaining factually information. The information obtained from these questions, were organized into two response tables fact finding/information driven questions and opinion based questions (see table 0.4 and table 0.5). Because this interviewee did not elaborate on many of his answers and the number of questions asked, were numerous, response tables were deemed the most appropriate method to convey the information. Further elaboration on these questions were unable to be given due to a lack of dialogue on the part of the interviewee. It should be noted that many of the questions in the question column are in an abbreviated form.

Fact Finding and Information Driven Questions

It was discussed above that most of the projects this company worked on were LEED based projects. By specializing in LEED projects, LEED standards were followed when it comes to the disposal of wallboard waste. From what was read in the literature and discussed with general contractors and waste management coordinators, recycling is not the typical disposal path employed by wallboard hangers. Although this company goes against the norm, it was interesting to learn about the consciousness this company took to reduce their wallboard waste. It should be noted, that when it comes to questions focused on waste creation, this interviewee was forthcoming by indicating that they were not perfect and waste generation at their project sites still occurs.

Table 0.4 Questions that focused on acquiring factual information from drywalling industry

Questions	Interviewee: Rosmar Drywall Employee
1. Is drywall waste separated or mixed	Separated
2. Who is responsible for its disposal	Depends on the contract it can either be the sub trade or general contractor. With LEED projects it is usually the responsibility of the general contractor
3. How is clean wallboard waste disposed of	Recycled in Oakville at New West Gypsum
4. How is contaminated wallboard waste disposed of	Only work on new projects sites therefore never deal with contaminated wallboard waste
5. What factor(s) influence the disposal decision employed	LEED standards
6. Percentage of wallboard waste discarded that is clean	100%
7. Do large wallboard scraps ever get transported to ones next project	No
8. Do large wallboard scraps that are clean get donated	No, usually do not have much scrap
9. Is wallboard exposed to the weather elements	Typically no, since the wallboard is covered. If it does happen only a couple of sheets are damaged a year
10. What are the environmental impacts connected with landfilling wallboard waste	Unaware
Under Validating Recommended Options	
3. Which material, composite panel or wallboard, is easiest to install	Wallboard
5. Are buildings designed to use standard size wallboard sheets	Yes
7. What factors influence the wallboard product one chooses	Depends on the architectural features
8. Is wallboard waste created due to changes made to the design of a project in which insufficient notice was given to the hanger	Yes, it happens on every project
9. Does one's company have an up-to-date product inventory list	Yes
10. Is wallboard waste sometimes created due to ordering errors	Yes
11. Do transportation practices lead to the on-site delivery of damage wallboard	Usually no
12. Does wallboard get damage while stored on-site	Typically no
13. Do you know of any wallboard recyclers in Southern Ontario	Yes, New West Gypsum
14. Do you use this facility	Yes, because of LEED

Opinion Based Questions

Table 0.5 Questions that focused on personal opinions

Questions	Interviewee: Rosmar Drywall Employee
Under Validating Recommended Options	
1. What problems will arise if wallboard is substituted with composite paneling	Composite panels will be harder to install
2. Is substituting wallboard with composite panel a feasible wall option	No
4. What on-site behaviors lead to the creation of wallboard waste	Poor storage, which lead to the damaging of wallboard
6. If wallboard was redesigned to be dissembled will disassembly happen in the future	It is not worth the effort
15. Is addition education needed on proper wallboard management practices	Maybe a little
16. Where is more education needed	Residential sector not so much the commercial sector
17.Would a just-in-time delivery approach change waste totals	Not an issue
18. What are best ways to get contractors to produce less waste	Financially

Appendix I : Result from Semi-structured Interview: General Contractors

Background

Due to liability concerns, company policy issues, and financial loss, semi-structure interviews were only conducted with two general contractors. The limitation of interviewing only two contractors is a weakened validity in the answers obtained. The use of other resources including literature sources and discussion with waste experts helped strengthen the validity in the responses and made this drawback no longer a concern. Once again a list of prepared questions, were drawn upon to ensure some standardization in the questions asked. The question list employed was similar to the one used by the researcher when interviewing the wallboard hanger (see appendix D). The purpose of these interviews was to: 1) understand how wallboard is managed by the construction industry; 2) who is primarily responsible for the generation of wallboard waste and what actions cause this waste to be created; and 3) how feasible is it to replace wallboard with another product or adopt new behaviors that will lead to reductions in wallboard waste totals.

Days, Times, and Business Background

The interview with Tom Keating of James Keating Construction was carried out over the phone. This general contracting firm is located Elora, Ontario and most of the construction projects this company focuses on are residential housing projects. This interview was held on March 30, 2009 and started at 9:45 am and ended twenty minutes later. The second interview was with a general contractor who worked for Greyhound Contracting Incorporated. This company is located in Waterloo, Ontario and they specialize in construction, renovation, and demolition of commercial, industrial, and institutional projects. This was an in-person interview held on April 3, 2009 at 2:35 pm at the University of Waterloo in the Student Life Center. It lasted approximately thirty-six minutes. Due to privacy concerns, this individual wished not to be identified in this project.

Response to Organization

Once again, not a lot of elaboration was provided by these interviewees. Due to a lack of discussion and the fact that thirty-three questions were asked, two different response tables were created (see table 0.6 and table 0.7). These tables were organized based on questions that were specifically fact/information driven versus questions that were trying to elicit personal opinions. In the cases where these individuals did elaborate on one of their responses, a more detailed discussion of that answer can be found below in the appropriate table. The questions found in the question section of each table are condensed versions of the actual question asked to these interviewees.

Fact Finding and Information Driven Questions

The focus of this subset of questions was to validate information acquired in the literature review as well as obtain facts about the current disposal practices employed by general contractors.

Table 0.6 Questions that focused on acquiring facts and information from general contractors

Questions	Interviewees	
	Tom Keating	**Greyhound Contracting Employee**
1. Is construction waste separated or mixed	Mixed	Degree of sorting – cardboard and metals, drywall is mixed with other waste
2. Who is responsible for this wastes disposal	Our company takes care of it	Depends on the contract sometimes it is the general contractor's responsibility other times it is the sub trades job
3. How is clean wallboard waste disposed of	Landfilled	Landfilled
4. How is contaminated wallboard waste disposed of	We do not deal with contaminated wallboard waste since all of our projects are new construction	Landfilled unless the panels contain hazardous material
5. What factor(s) influence the disposal decision employed	Cost	Cost, convinces, and awareness
6. Percentage of wallboard waste discarded that is clean	100%	33% clean 66% contaminated since most of our projects have some sort of demolition involved
7. Do large wallboard scraps ever get transported to ones next project	Yes	Only full sheets
8. Do large wallboard scraps that are clean get donated	No	Unaware that donation centers would accept this material
9. Is wallboard exposed to the weather elements	No	No - we get drywall delivered when we needed it and it is stored inside
10. What are the environmental impacts connected with landfilling wallboard waste	Do not know	Not aware of any
Under Validating Recommended Options		
4. Which material, composite panel or wallboard, is easiest to install	Wallboard because it is easier to cut	Wallboard
6. Are buildings designed to use standard size wallboard sheets	No	There is probably some consideration, but most building are designed based on the least amount of masonry cutting needed
8. What factors influence the wallboard product one chooses	Cost and ease of installation	Fire rating, recommendation made by architects, cost, and acoustics
9. Is wallboard waste created due to changes made to the design of a project in which insufficient notice was given to the hanger	No	I do not know
10. Does one's company have an up-to-date product inventory list	No, everything ordered gets shipped and used at the job site	No, little inventory is carried at our company
12. Is wallboard waste sometimes created due to ordering errors	No, because if we have excess it gets moved to our next site	Possibly, but if this would happen we would try and return it

13. Do transportation practices lead to the on-site delivery of damage wallboard	A little bit	Usually no, if it does we will still use these pieces
14. Does wallboard get damage while stored on-site	Yes, the odd time but we try and get it delivered when we need it	Not at our sites
17. Do you know of any wallboard recyclers in Southern Ontario	Yes, there use to be one in Elmira	I think there is a firm in Niagara Falls
18. Do you use this facility	No	We have no need to use them

In terms of who is responsible for the disposal of construction waste, the Greyhound employee explained that typically, their company encourages all sub trades to take care of their own waste. With some trade workers, however, they prefer us to handle the disposal procedures. In instances where the sub trader wants us to manage their waste, we will usually accommodate this request. This employee went on to discuss how all nonhazardous wallboard waste is discarded in landfills. Anytime wallboard waste contains hazardous materials like lead paint or asbestos, Greyhound brings in a licensed waste management firm to deal with the contaminated wallboard. This company must be licensed by the Ministry of Labour and follow the hazardous procedures the ministry has established.

Another question, in which both interviewees offered further insight, was question eight, which was interested in determining what factors influence the wallboard product your company uses. In the case of Mr. Keating, he explained that wallboard decisions are typically up to the contactor as long as the choice satisfies building code requirements. He went on to discuss how architects are typically not involved in residential housing projects. As long as the contractor is a certified designer, the selection of materials is completely left up to the general contractor and their client. In the case of the Greyhound employee, he talked about a new type of high impact drywall that is now on the market. He also discussed the importance of selecting drywall that has a high enough rating and thickness to muffle unwanted noises. The example he gave involved a 25% reduction in noise if a 5/8 inch panel was used over 1/2 inch panel. He explained that knowing the difference in panel function is a key factor when deciding what panel to use.

Opinion Based Question

Table 0.7 Questions that focused on general contractors personal opinions

Questions	**Interviewees**	
	Tom Keating	**Greyhound Contracting Employee**
11. What behaviors have shown the greatest success in improving other problematic construction waste	Unsure	Regulations
Under Validating Recommended Options		
1. What problems will arise if wallboard is substituted with composite paneling	There will be no problems	Fire rating and appearance
2. Is substituting wallboard with composite panel a feasible wall option	It depends on cost	As long as there is demand and we are directed to use it we will
3. What effect would this have on employment	None	Gradual transition from wallboard hangers to composite panel installers
5. What on-site behaviors lead to the creation of wallboard waste	Poor installation techniques, a lack of experience, and piece work	Poor site supervision and unskilled workers
7. If wallboard was redesigned to be dissembled will disassembly happen in the future	No	The construction industry already has demountable wallboard
11. Do you think it is important to have a clause in your trade workers contract that make them responsible for any wasteful practices they employ	It would be good	It would be good, but difficult to enforce
15. If waste reduction initiatives are implement what will its effect be on landfill disposal fees	Disposal fees will probably stay the same – if waste reduction initiative are not implemented increase disposal fees will happen	I do not know
16.How high will landfills tipping fees have to go before change starts to happen	I do not know	It would have to double
19. Is addition education needed on proper wallboard management practices	No	Yes
20. Where is more education needed	Nowhere	Waste reduction and better disposal techniques
21. Would a just-in-time delivery approach change waste totals	Yes	Yes
22. What are best ways to get contractors to produce less waste	Financially –Hit this industry where it hurts them	Provide them education and financial disincentives

There were several questions in which these interviewees provided further information. In terms of what behaviors in the past have shown to have the greatest success in improving other problematic waste, the Greyhound employee explained the impact that regulations have played on this industry. Stricter regulations and more expensive disposal fees in place will forces the construction industry to develop new and better ways to deal with this waste. Examples where these two actions have improved other problematic construction waste are with wood and concrete. Today, these two materials are no longer landfilled instead they are recycled and processed into new sellable products.

In terms of what problems will arise if wallboard is replace with composite panels, a major concern raised by the Greyhound employee was the panel's workability. You only need a knife to work with drywall. If your cuts are not perfect, the wallboard is forgiving. Drywall is a user friendly material, which a lot of skilled workers know how to install. If you introduce another product you want to make sure it is just as easy to work with or this industry will not be accepting of this new material.

In further discussions of what on-site behaviors lead to the creation of unnecessary waste, Mr. Keating explained that not using off-cuts is a significant contributor to wallboard waste creation. Drywallers pay is based on the square footage of drywall they install. Their pay also includes the wallboard off-cuts they discard. The fact they are getting paid to throw out pieces of wallboard is where the problem lies. He explained that if you force these individuals to use the off-cuts, not only would it take a longer time to create a wall, but the wall's finish will be worse. Right now we are in a no win situation. If we try to use our off-cut in order to produce less waste, the end product created will be of lower quality.

The last question, for which further elaboration was offered, involved demountable wallboard. The Greyhound employee explained that the construction industry has come up with a demountable wallboard, but that it tends to be used only in office buildings. The problem with demountable wallboard is that holes are needed for light switches and electrical outlets. When this wallboard is moved or rearranged, these holes will most likely be in the wrong location for the new light switches and electrical outlets. As a result, certain boards have to be replaced. So although these boards exist, they are not that useful.

Unique Points Raised

Once interesting side comments made by the Greyhound employee was:

- Drywall pieces are sometimes discarded in the middle of walls. The higher up a project is, the smaller the timeframe, and the more short staff a company is, the more likely wallboard off-cuts will be thrown between the walls in order to save time and reduce disposal costs (Greyhound Employee, 2009).